Indiana Department of Environmental Management
Office of Air Quality
www.idem.IN.gov

An Assessment of the American Meteorological Society/U.S. EPA Regulatory Model's (AERMOD's) Accuracy: A Case Study - REVISED

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UPDATE

This report was originally released in May of 2015. Since that time there have been errors found in the report. The original report should not be relied on for any conclusions. This analysis compares monitored sulfur dioxide (SO2) levels with predicted SO2 levels from AERMOD. The values compared were both believed to be in the same units – parts per billion (ppb). However, it turns out that the monitored values were in parts per billion, but the predicted values consisted of modeled values in micrograms per cubic meter with background levels added in parts per billion. This means that the predicted levels were too high. This revised report corrects this error and compares both values in parts per billion.

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EXECUTIVE SUMMARY

This analysis compares predicted and observed sulfur dioxide (SO2) levels at the Gibson power plant in southwestern Indiana. Actual hourly SO2 emission rates for 2010 were modeled in AERMOD and compared to SO2 levels measured at four monitors near the plant. Modeling was conducted using Evansville meteorological data (Scenario 2) and on-site meteorological data (Scenario 3).

Using Evansville meteorological data, AERMOD predicted 13 hours of exceedances of the 1-hour standard. The monitors measured 10 hours of exceedances in 2010.

Direct comparisons of predicted and observed SO2 levels indicate that AERMOD significantly over-predicts by more than a factor of two. If comparisons are made using U.S. EPA's preferred approach, the analyses still shows that AERMOD agrees well with measurements.

Using on-site meteorological data, AERMOD predicted 47 hours of exceedances of the 1-hour standard. The monitors measured 10 hours of exceedances during this period.

Direct comparisons of predicted and observed SO2 levels indicate that AERMOD significantly over-predicts by more than a factor of two. If comparisons are made using U.S. EPA's preferred approach, the analyses shows that AERMOD agrees well with measurements.

This analysis discovered that AERMOD often "blows up" when modeling low wind speeds (less than one meter per second). Under these conditions the model predicts high concentrations at all receptors regardless of wind direction.

We believe that this analysis demonstrates concerns with the use of AERMOD without making modifications to improve agreement between predicted and observed values and to reduce the amount of over-prediction.

In the final analysis, the performance of AERMOD rests on whether comparisons are made in time and space (as IDEM recommends) or only in space (as U.S. EPA recommends).

ACKNOWLEDGEMENTS

I would like to thank several persons for their assistance in getting this project accomplished. First, I would like to thank Brian Callahan and Mark Neyman of my staff who put together the files and made the modeling runs. Also thanks to Kali Frost and Eric Bailey, former staff members, who oversaw much of the preliminary analytical work.

Thanks to Randy Robinson of U.S. EPA Region V for his review and comments during this analysis. Special thanks to Chet Wayland, Roger Brode and Tyler Fox of the U.S. EPA's Office of Air Quality, Planning and Standards (OAQPS).

A final thanks to my Administrative Assistant, Agripina Sturgis, who put this report together.

BACKGROUND

In December of 2010 Indiana was faced with modeling over a hundred industrial sources to establish sulfur dioxide (SO2) limits necessary to comply with the one-hour standard. Prior to beginning this effort, I called Chet Wayland, Division Director at the U.S. EPA's Office of Air Quality, Planning and Standards (OAQPS) and asked how accurate the AERMOD model was. Instead of referring me to other studies, Chet asked us to conduct an analysis to demonstrate the relationship between AERMOD predictions and ambient measurements. This report documents the work carried out to answer this question.

It should be noted that IDEM's interest in doing this study was:

1) **To demonstrate that AERMOD worked very well.**
2) **To demonstrate that AERMOD did not work well and to work with the U.S. EPA to make corrections to improve performance.**

This analysis has taken a long time to reach this stage. During this review the version of AERMOD has changed, thoughts on how to carry out the comparisons or make the model estimates have changed and staff working on this project have left to take other jobs.

This analysis describes the methodology used for testing the model; the data used and provides several different analyses of the data.

In the end we want to be able to answer the question of how well does AERMOD predict 1-hour sulfur dioxide concentrations and if it does poorly are there refinements that can be made to improve model performance.

FACILITY

The Indiana Department of Environmental Management (IDEM) decided to test the performance of AERMOD by comparing model predictions with measured sulfur dioxide values near the Duke – Gibson power plant in southwestern Indiana. This facility was selected for several reasons:

1) **It is located such that it is not impacted by other nearby SO2 sources.**
2) **It has continuous emission monitors (CEMs) on each of its stacks so that hourly SO2 emission rates are known.**
3) **It has four SO2 monitors surrounding the facility.**
4) **It has a three level meteorological tower on-site taking numerous meteorological parameters.**

The year of 2010 was selected for analysis. Model predictions were made at the four monitoring sites under three meteorological scenarios. The first was to use on-site meteorological data prepared in the standard way. The second was to model using data from the nearest National Weather Service (NWS) station (Evansville) which is located approximately 40 kilometers south of the plant. The third scenario was to use on-site meteorological data, but to process it from the top down. Only results from the final two scenarios are included in this report. The U.S. EPA believes that the on-site data processed in the typical fashion is influenced by a nearby cooling pond. By processing the data from the top down, this problem should be minimized.

Modeling was based on actual hourly emission rates for each stack. This is an important point. Since emission rates vary by hour it is not appropriate to compare the data unless it is paired in time. You cannot compare the highest modeled and highest monitored hourly values for a site.

They may be based on very different emission totals or distributions of emissions by stack. This will be discussed in greater detail later.

Figure 1 shows the locations of the five stacks versus the four sulfur dioxide monitors. Winds from the following directions blow directly from the stacks to the four monitors:

Site	*Wind Direction Range (degrees)*
Mt. Carmel	169 – 172
Coal Road	214 – 219
East	297 – 300
Schrodt	87 – 90

All modeled values contain a background SO2 value. This background level is determined for each hour and is based on the lowest of the four monitored values for each hour.

SCENARIO 2 RESULTS

Scenario 2 involves modeling using National Weather Service data from Evansville which is approximately 40 kilometers south of the Gibson facility.

All Data

The first set of results included all data where the hour has both a modeled and a monitored concentration. Those hours where monitored values were missing were excluded from the analysis.

Mt. Carmel Site

Figure 2 shows a comparison of modeled and monitored concentrations compared in time for the Mt. Carmel site. The line from the lower left corner to the upper right corner shows where the model and monitor would perfectly agree. The dashed lines show the factor of 2 areas. The dashed line above the continuous line is the area where the model under-predicts but is within a factor of 2 of the monitored value. If values are above this line, the values under-predict the monitored value by more than a factor of 2. The dashed line at the bottom of the chart is the line of over-prediction. Values above this line are within a factor of two, but are over-predicted by AERMOD. Values that are below this line are over-predicted by more than a factor of two. Of the 8,212 hours of data, 86.8 percent are within a factor of 2, 4.6 percent are under-predicted and 8.6 percent are over-predicted.

Figure 1

Gibson Generating Station

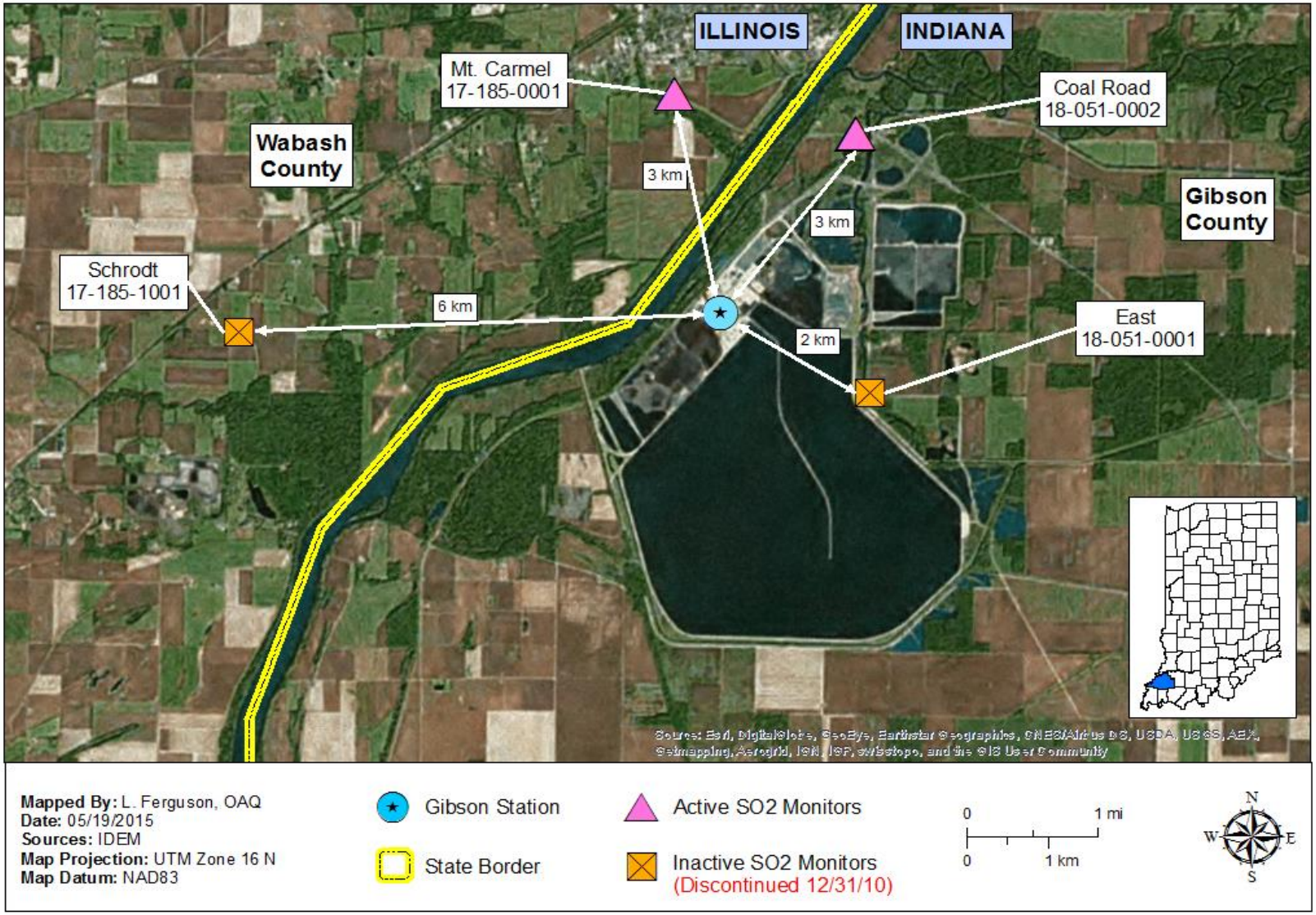
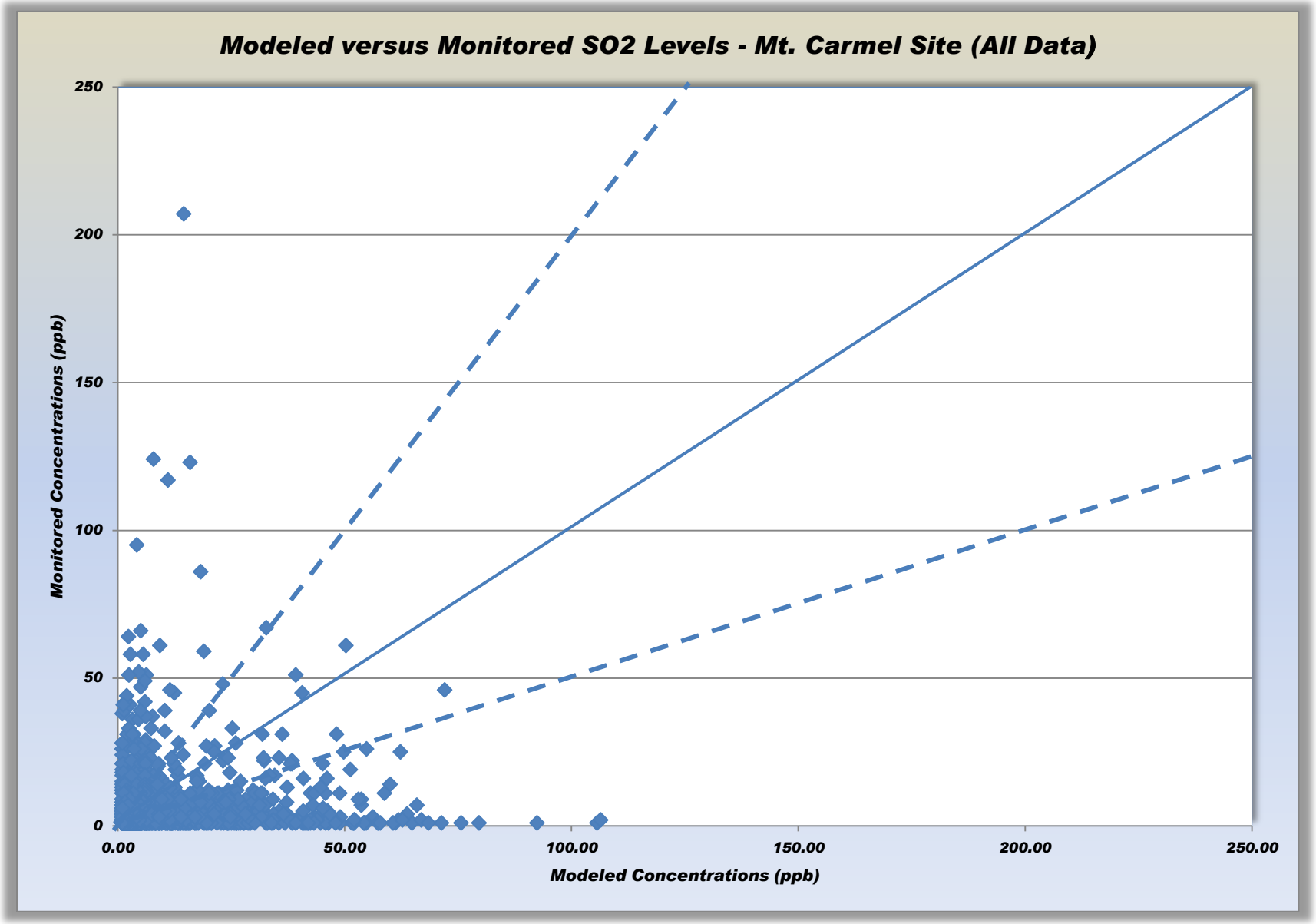


Figure 2


Modeled versus Monitored SO2 Levels - Mt. Carmel Site (All Data)
Monitored Concentrations (ppb)
250
200
150
100
50
0
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

East Site

Figure 3 shows a comparison of modeled and monitored concentrations compared in time for the East site. Of the 8,357 hours, 82.9 percent are within a factor of 2, 9.4 percent are under-predicted and 7.7 percent are over-predicted.

Coal Road Site

Figure 4 shows a comparison of modeled and monitored concentrations compared in time for the Coal Road site. Of the 8,347 hours, 75.8 percent are predicted within a factor of 2, 16.5 percent are under-predicted and 7.7 percent are over-predicted.

Schrodt Site

Figure 5 shows a comparison of modeled and monitored concentrations compared in time for the Schrodt site. Of the 6,357 hours, 76.5 percent are predicted within a factor of 2, 20.7 percent are under-predicted and 2.8 percent are over-predicted.

SUMMARY

Table 1 summarizes the results for all four sites. Overall 80.5 percent of the predictions are within a factor of 2 of the measured values, 12.8 percent are under-predicted and 6.7 percent are over-predicted. On a first glance it would appear that AERMOD is working well. The majority of the predictions are within a factor of two and the amount of over-predictions is nearly equal to the number of under-predictions. Later results will explain why this is not the case.

Table 1

Results of Scenario 2 Analyses – All Data

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**
<0.5	378	4.6	789	9.4	1376	16.5	1724	20.7	4267	12.8
0.5 – 2.0	7130	86.8	6926	82.9	6383	75.8	6357	76.5	26736	80.5
➢ **2.0**	704	8.6	642	7.7	648	7.8	232	2.8	2226	6.7
Total	8212		8357		8347		8313		33229	

Figure 3

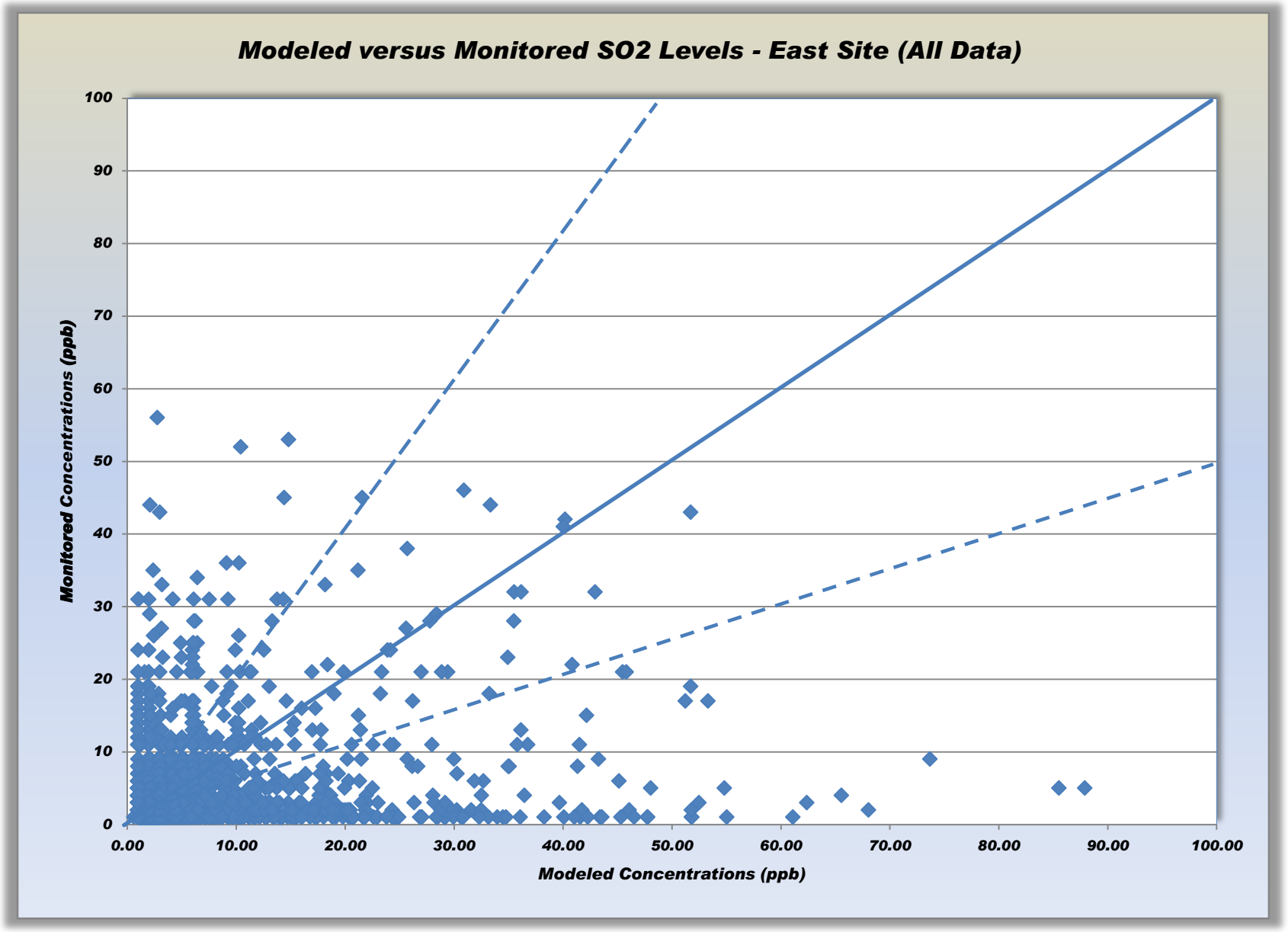
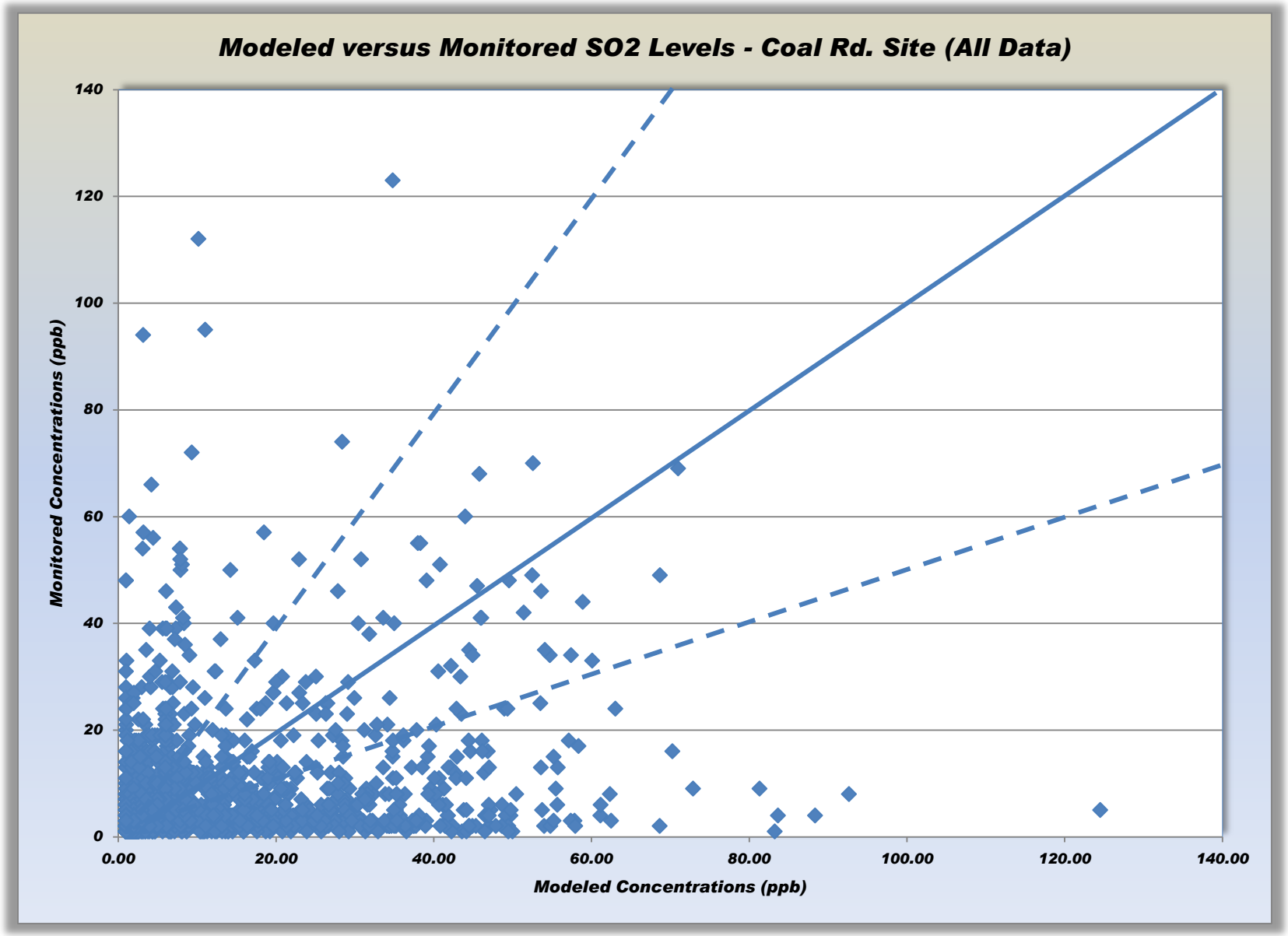

Modeled versus Monitored SO2 Levels - East Site (All Data)
Monitored Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
100
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Modeled Concentrations (ppb)

Figure 4


Modeled versus Monitored SO2 Levels - Coal Rd. Site (All Data)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Wind Speed Analysis

Table 2 shows the average ratio of modeled divided by monitored concentrations versus wind speed. There does not appear to be a strong relationship between wind speed and the ratio of modeled to monitored concentrations. It should be noted that not all wind speed categories have the same number of readings. The greater than 10 meters per second category has very few readings. Any conclusions based on this category may be questionable.

Table 2

Comparison of Average Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	1.12	0.96	0.66	0.69
1.01 – 2	1.50	1.46	1.19	0.95
2.01 – 3	2.10	1.60	1.05	0.96
3.01 – 4	1.92	1.47	1.14	0.83
4.01 – 5	1.60	1.14	1.48	0.78
5.01 – 6	1.61	1.26	1.33	0.82
6.01 – 7	1.57	1.09	1.68	0.86
7.01 – 8	1.15	0.88	1.37	0.80
8.01 – 9	1.00	0.89	1.86	0.75
9.01 – 10	0.95	0.91	1.68	0.79
➢ 10	0.83	0.86	2.66	0.95

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 3 shows the median ratios versus wind speed. In most cases this shows that the ratios are between 0.5 and 1, within the factor of two ranges.

Table 3

Comparison of Median Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	1.00	1.00	0.50	0.50
1.01 – 2	1.00	1.00	0.50	0.67
2.01 – 3	1.00	1.00	0.67	0.73
3.01 – 4	1.00	1.00	0.67	0.72
4.01 – 5	1.00	1.00	0.67	0.75
5.01 – 6	1.01	1.00	0.63	1.00
6.01 – 7	1.03	1.00	0.67	1.00
7.01 – 8	1.02	1.00	0.67	1.00
8.01 – 9	1.02	1.02	0.69	0.75
9.01 – 10	1.00	1.00	0.63	1.00
➢ 10	1.00	1.00	1.00	1.01

Wind Direction Analysis

Table 4 compares average modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 4

Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	0.99	0.86	0.61	0.69
11 – 20	1.02	0.96	0.70	0.76
21 – 30	1.05	1.01	0.71	0.69
31 – 40	1.07	0.93	0.71	0.64
41 – 50	1.00	0.95	0.71	0.60
51 – 60	0.93	0.85	0.64	0.60
61 – 70	0.98	0.94	0.69	0.82
71 – 80	1.04	0.99	0.77	0.91
81 – 90	1.07	1.08	0.74	2.85
91 – 100	1.05	1.05	0.76	1.99
101 – 110	0.98	1.04	0.70	1.45
111 – 120	1.01	1.08	0.78	1.17
121 – 130	0.98	1.18	0.78	0.81
131 – 140	0.91	0.94	0.70	0.78
141 – 150	1.64	1.00	0.74	0.77
151 – 160	2.98	1.40	0.87	0.82
161 – 170	**7.24**	1.12	0.72	0.77
171 – 180	**11.38**	1.08	0.74	0.78
181 – 190	3.27	1.02	0.80	0.76
191 – 200	1.94	1.08	1.17	0.79
201 – 210	1.24	1.01	2.12	0.79
211 – 220	1.21	1.13	**4.49**	0.73
221 – 230	1.17	1.13	3.78	0.77
231 – 240	1.19	1.14	2.49	0.73
241 – 250	1.31	1.31	1.43	0.83
251 – 260	1.10	1.09	0.73	0.72
261 – 270	1.19	1.30	0.66	0.81
271 – 280	1.15	1.57	0.71	0.80
281 – 290	1.19	2.96	0.70	0.82
291 – 300	1.12	**3.26**	0.69	0.77
301 – 310	1.06	**2.84**	0.74	0.70
311 – 320	1.03	2.48	0.68	0.79
321 – 330	1.13	2.37	0.71	0.78
331 – 340	1.18	1.31	0.75	0.87
341 – 350	1.17	1.05	0.71	0.81
351 – 360	1.00	0.87	0.67	0.80

For the key wind directions the average ratios are higher than two. This would indicate that in the directions where the wind is blowing from the stacks to the monitors, the disagreement between the model and the monitor is greatest.

Table 5
Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.00	1.00	0.50	0.67
11 – 20	1.00	1.00	0.55	0.75
21 – 30	1.00	1.00	0.67	0.63
31 – 40	1.00	1.00	0.65	0.52
41 – 50	1.00	1.00	0.50	0.50
51 – 60	1.00	1.00	0.50	0.50
61 – 70	1.00	1.00	0.50	0.50
71 – 80	1.00	1.00	0.67	0.60
81 – 90	1.00	1.00	0.67	1.00
91 – 100	1.00	1.00	0.67	1.00
101 – 110	1.00	1.00	0.61	1.00
111 – 120	1.00	1.00	0.67	0.67
121 – 130	1.00	1.00	0.58	0.67
131 – 140	1.00	1.00	0.67	0.75
141 – 150	1.00	1.00	0.67	0.76
151 – 160	1.00	1.00	0.67	1.00
161 – 170	1.94	1.00	0.66	0.86
171 – 180	2.24	1.00	0.53	0.98
181 – 190	1.00	1.00	0.52	0.72
191 – 200	1.00	1.00	0.56	0.83
201 – 210	1.00	1.00	0.76	1.00
211 – 220	1.00	1.00	1.38	0.61
221 – 230	1.00	1.00	1.00	0.77
231 – 240	1.00	1.00	0.67	0.63
241 – 250	1.00	1.00	0.67	0.88
251 – 260	1.00	1.00	0.51	0.60
261 – 270	1.00	1.00	0.53	0.67
271 – 280	1.00	1.00	0.56	0.67
281 – 290	1.00	0.75	0.53	0.73
291 – 300	1.00	0.75	0.56	0.67
301 – 310	1.00	0.83	0.67	0.75
311 – 320	1.00	0.86	0.57	1.00
321 – 330	1.00	1.00	0.59	1.00
331 – 340	1.00	1.00	0.54	1.00
341 – 350	1.00	1.00	0.52	1.00
351 – 360	1.00	1.00	0.57	0.81

Table 5 shows the median ratios of modeled to monitored concentrations versus wind direction. Once again the key wind directions show the largest discrepancies between the modeled and monitored concentrations.

Comparisons Not in Time

The U.S. EPA does not believe that these values should be paired in time. While we do not agree we wish to show the results of such an analysis. In this case the modeled and monitored values are ranked from lowest to highest and then paired. Figures 6 through 9 show the results. For the Mt. Carmel site (Figure 6) AERMOD predicts all values within a factor of two. The East site (Figure 7) shows an AERMOD predicts all values within a factor of two. The Coal Road site

(Figure 8) shows that 97.4 percent of all readings are within a factor of two, while 2.5 percent are under-predicted. Only 5 values are over-predicted. The Schrodt site (Figure 9) shows 92.3 percent of all values within the factor of two and 7.7 percent under-predicted.

IDEM believes that it is not appropriate to compare the data in this fashion. Since each hour has a different emission rate, comparison of different hours is comparing apples and oranges. Without making corrections for emission rates an accurate assessment of a comparison of this type is not appropriate.

However, it may be possible to compare the data without actually comparing individual hours at all. Table 6 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the number of hours that exceed the standard of 35 parts per billion (ppb). For the Mt. Carmel site AERMOD predicts 5 hours above the standard, while the monitor measured 6. For the East site AERMOD predicts 2 hours above the standard, while the monitor measured none. For the Coal Road site AERMOD predicts 6 hours above the standard while the monitor measured 4. For the Schrodt site AERMOD predicts no hours above the standard while the monitor measured none. This seems to indicate that AERMOD predicts similarly to what is being measured.

Figure 5

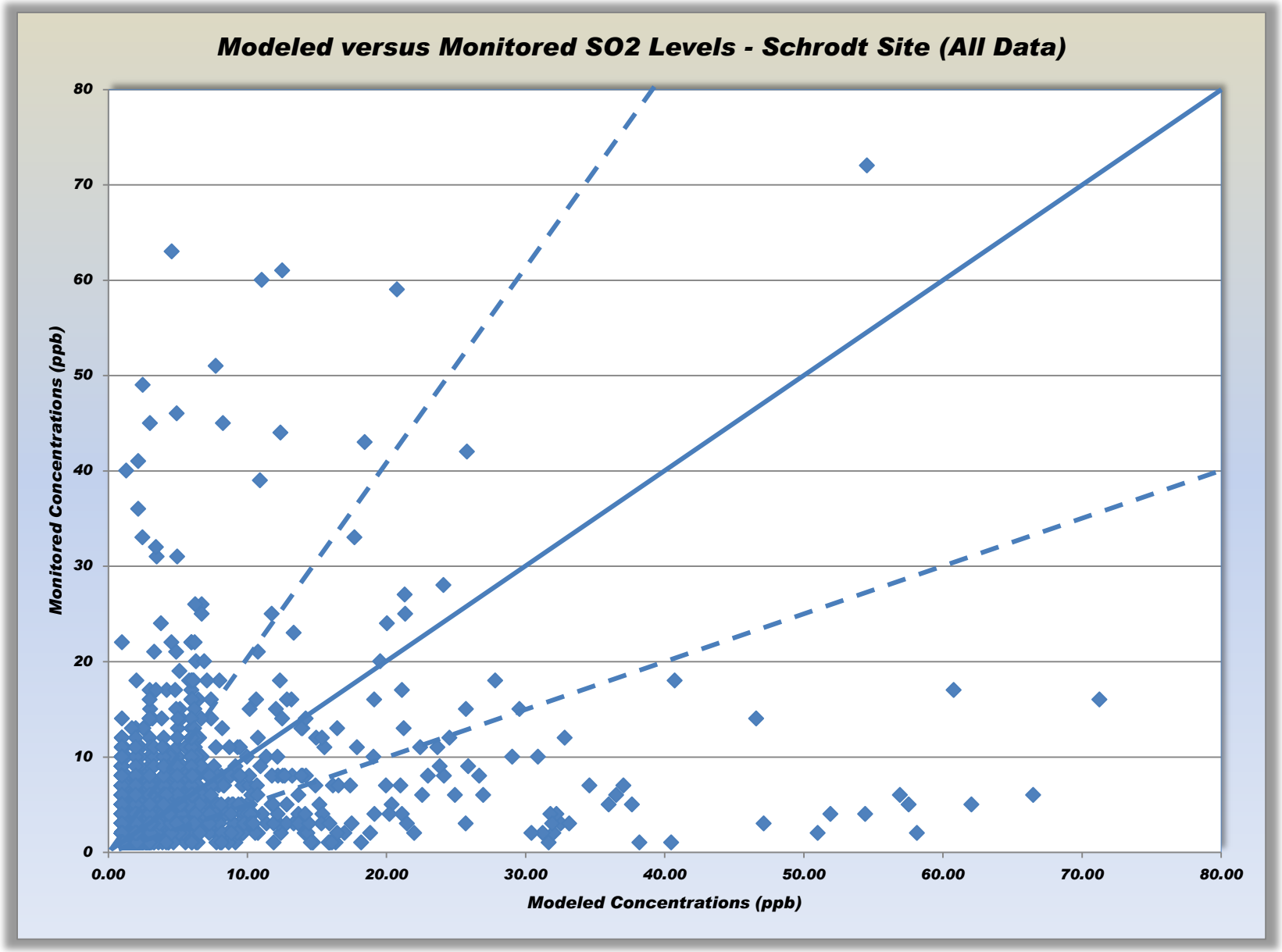

Modeled versus Monitored SO2 Levels - Schrodt Site (All Data)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

Figure 6

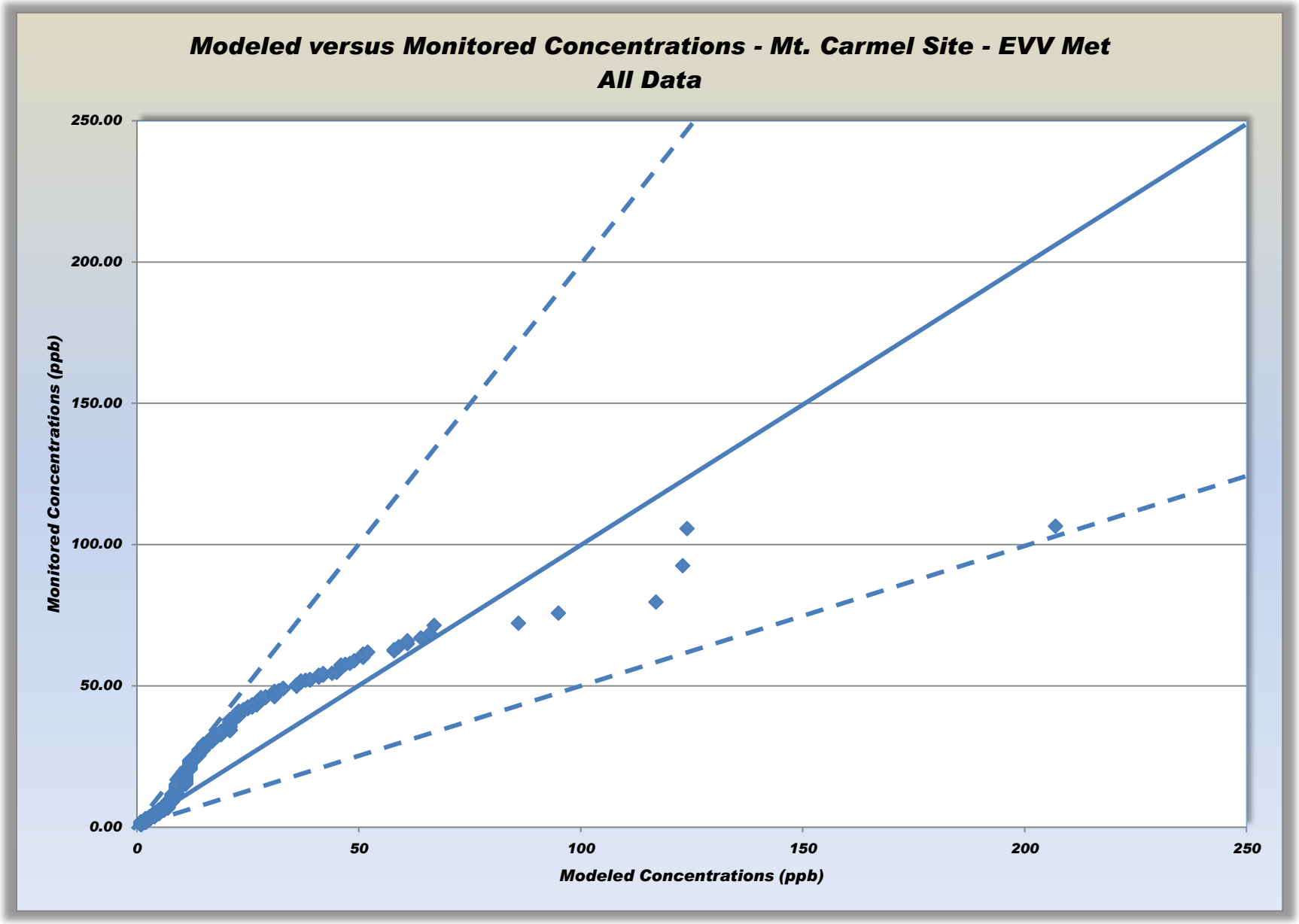

Modeled versus Monitored Concentrations - Mt. Carmel Site - EVV Met
All Data
250.00
200.00
150.00
100.00
50.00
0.00
Monitored Concentrations (ppb)
0
50
100
150
200
250
Modeled Concentrations (ppb)

Figure 7

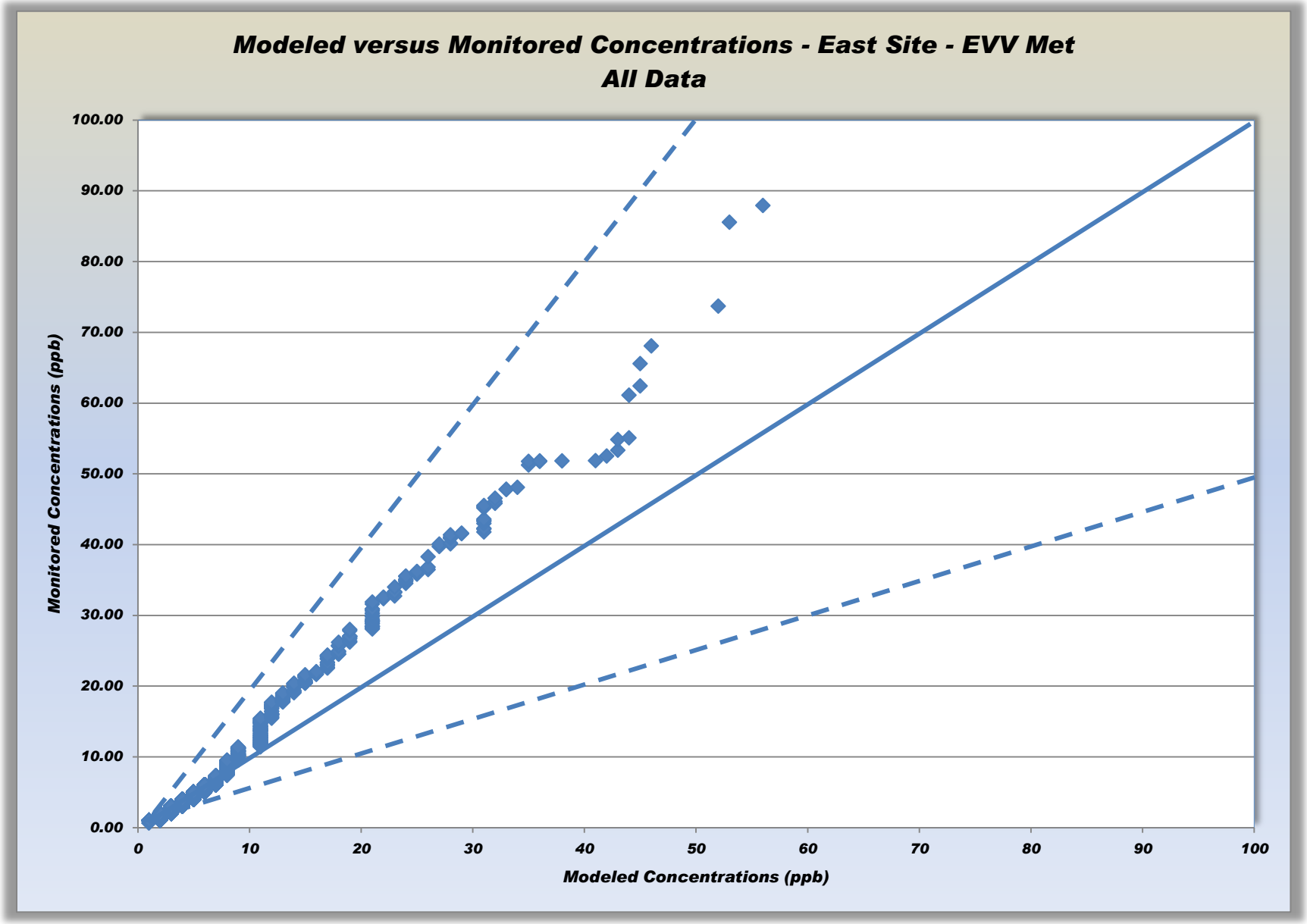

Modeled versus Monitored Concentrations - East Site - EVV Met
All Data
Monitored Concentrations (ppb)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
40
50
60
70
80
90
100
Modeled Concentrations (ppb)

Figure 8

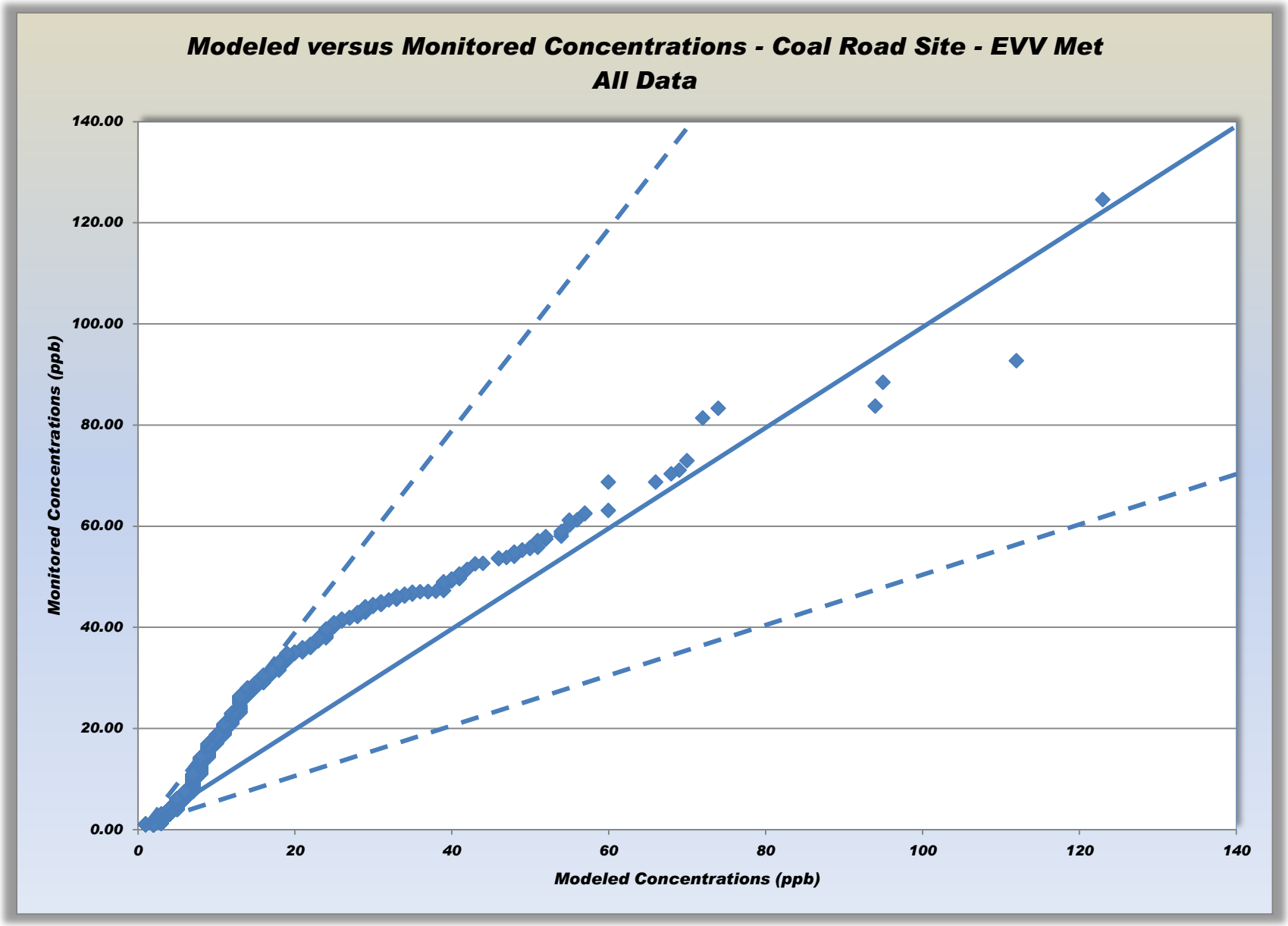

Modeled versus Monitored Concentrations - Coal Road Site - EVV Met
All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0
20
40
60
80
100
120
140

Figure 9

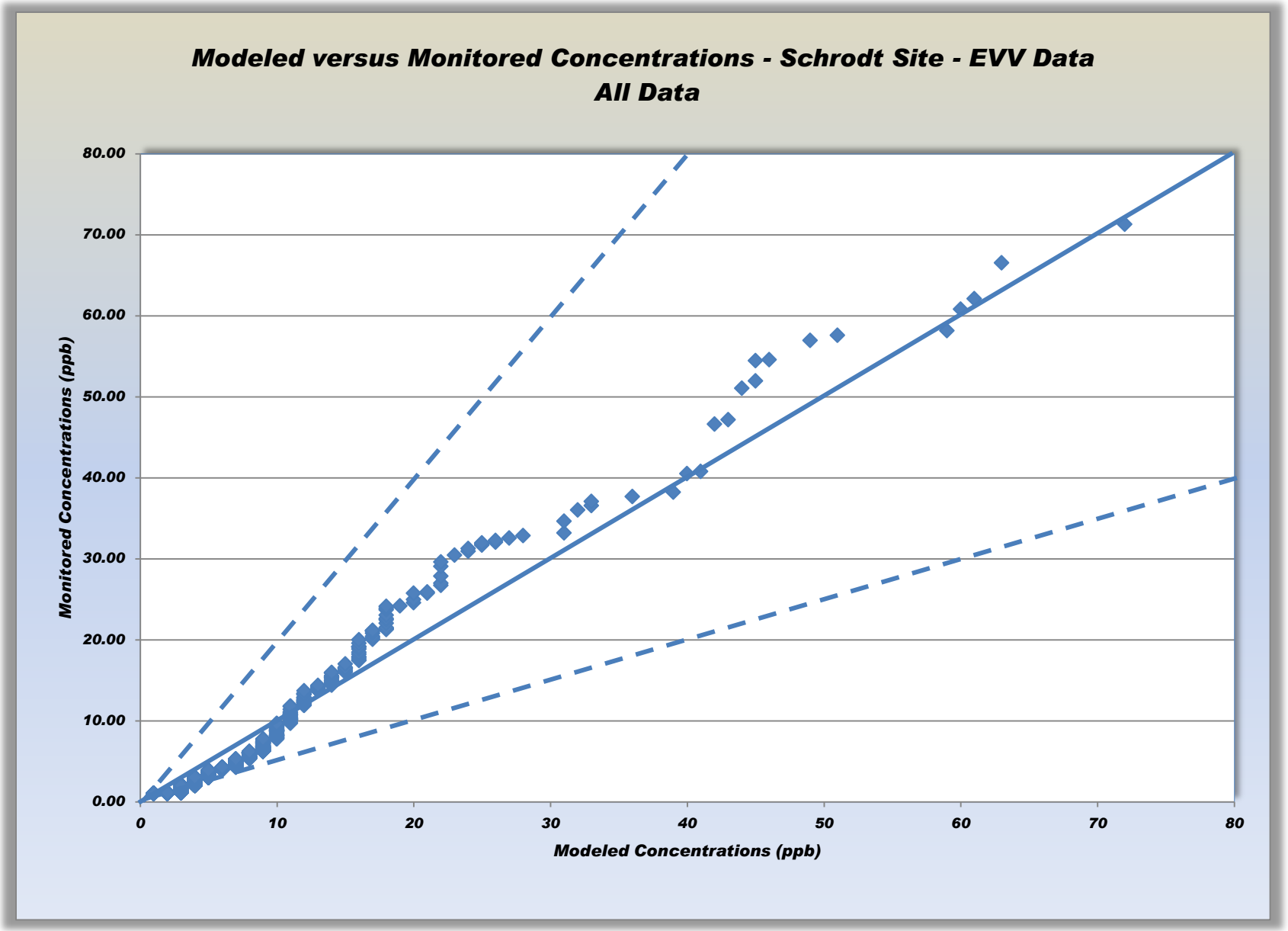

Modeled versus Monitored Concentrations - Schrodt Site - EVV Data
All Data
Monitored Concentrations (ppb)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
40
50
60
70
80
Modeled Concentrations (ppb)

Table 6
Hours within Selected Ranges – Scenario 2 – All Data

	Mt. Carmel		East		Coal Road		Schrodt	
Range	**Model**	**Monitor**	**Model**	**Monitor**	**Model**	**Monitor**	**Model**	**Monitor**
1 – 25	8038	8146	8257	8312	8069	8245	8272	8287
26 – 50	48	136	83	42	278	77	30	20
51 – 75	33	12	15	3	36	21	11	6
76 – 100	3	2	2	0	5	2	0	0
101 – 125	2	3	0	0	1	2	0	0
126 – 150	0	0	0	0	0	0	0	0
151 – 175	0	0	0	0	0	0	0	0
176 – 200	0	0	0	0	0	0	0	0
201 – 225	0	1	0	0	0	0	0	0
Total	8212	8212	8357	8357	8347	8347	8313	8313
Above 75	5	6	2	0	6	4	0	0

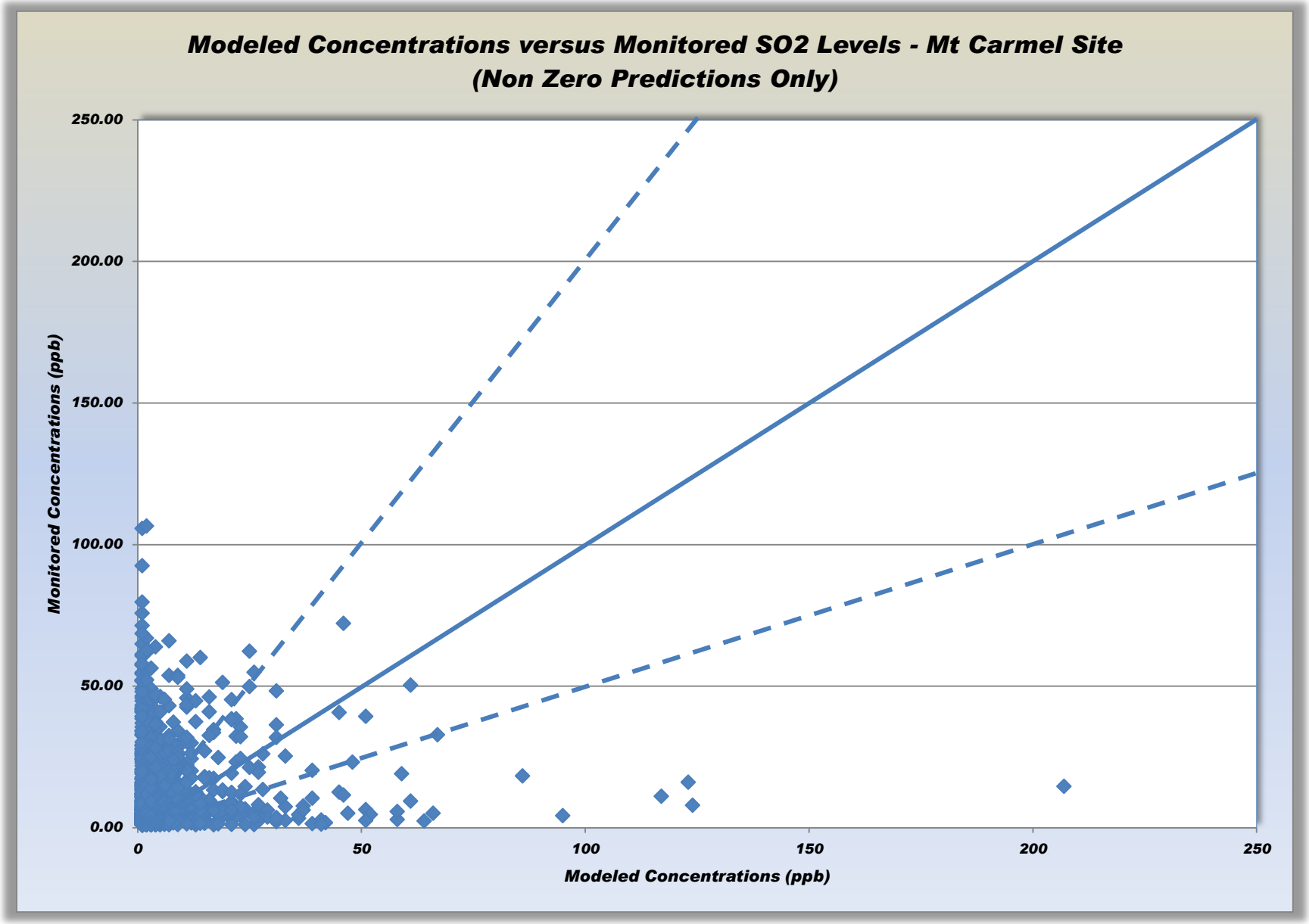
Non-Zero Predictions Only

The analyses presented so far have used all data where both the predicted and the monitored values are available for an hour. However the majority of these readings are non-meaningful. In most cases AERMOD predicts a zero value which then has a background value added and then is compared to the monitored value. This is not a true measure of how the model is working. Model predictions of zero are of little interest except for computing an annual average value. This set of analyses removes all hours where the AERMOD predicted value was zero.

Mt. Carmel Site

Figure 10 shows a comparison of predicted and measured SO2 levels compared in time for the Mt. Carmel site. Of the 3,402 hours of data, 73.5 percent are predicted within a factor of two, while 6.2 percent are under-predicted by more than a factor of two and 20.3 percent are over-predicted by more than a factor of two.

Figure 10


Modeled Concentrations versus Monitored SO2 Levels - Mt Carmel Site
(Non Zero Predictions Only)
250.00
200.00
150.00
100.00
50.00
0.00
Monitored Concentrations (ppb)
0
50
100
150
200
250
Modeled Concentrations (ppb)

East Site

Figure 11 shows a comparison of predicted and measured SO2 levels compared in time for the East site. Of the 3,253 hours of data, 72.7 percent are predicted within a factor of two, while 7.9 percent are under-predicted by more than a factor of two and 19.4 percent are over-predicted by more than a factor of two.

Coal Road Site

Figure 12 shows a comparison of predicted and measured SO2 levels compared in time for the Coal Rd. site. Of the 3,481 hours of data, 67.6 percent are predicted within a factor of two, while 13.7 percent are under-predicted by more than a factor of two and 18.7 percent are over-predicted by more than a factor of two.

Schrodt Site

Figure 13 shows a comparison of predicted and measured SO2 levels compared in time for the Schrodt site. Of the 3,455 hours of data, 76.9 percent are predicted within a factor of two, while 16.8 percent are under-predicted by more than a factor of two and 6.3 percent are over-predicted by more than a factor of two.

SUMMARY

Table 7 summarizes the results for all four sites. Overall 72.7 percent of the predictions are within a factor of two of the measured values, 11.2 percent are under-predicted by more than a factor of two and 16.1 percent are over-predicted by more than a factor of two. The performance of AERMOD is not as good as shown earlier. Fewer predictions are within the factor of two and more over-predictions are occurring as under-predictions.

Table 7
Results of Scenario 2 Analyses – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**
<0.5	210	6.2	255	7.9	477	13.7	580	16.8	1522	11.2
0.5 – 2.0	2499	73.5	2366	72.7	2352	67.6	2657	76.9	9874	72.7
➢ **2.0**	693	20.3	632	19.4	652	18.7	218	6.3	2195	16.1
Total	3402		3253		3481		3455		13591	

Figure 11

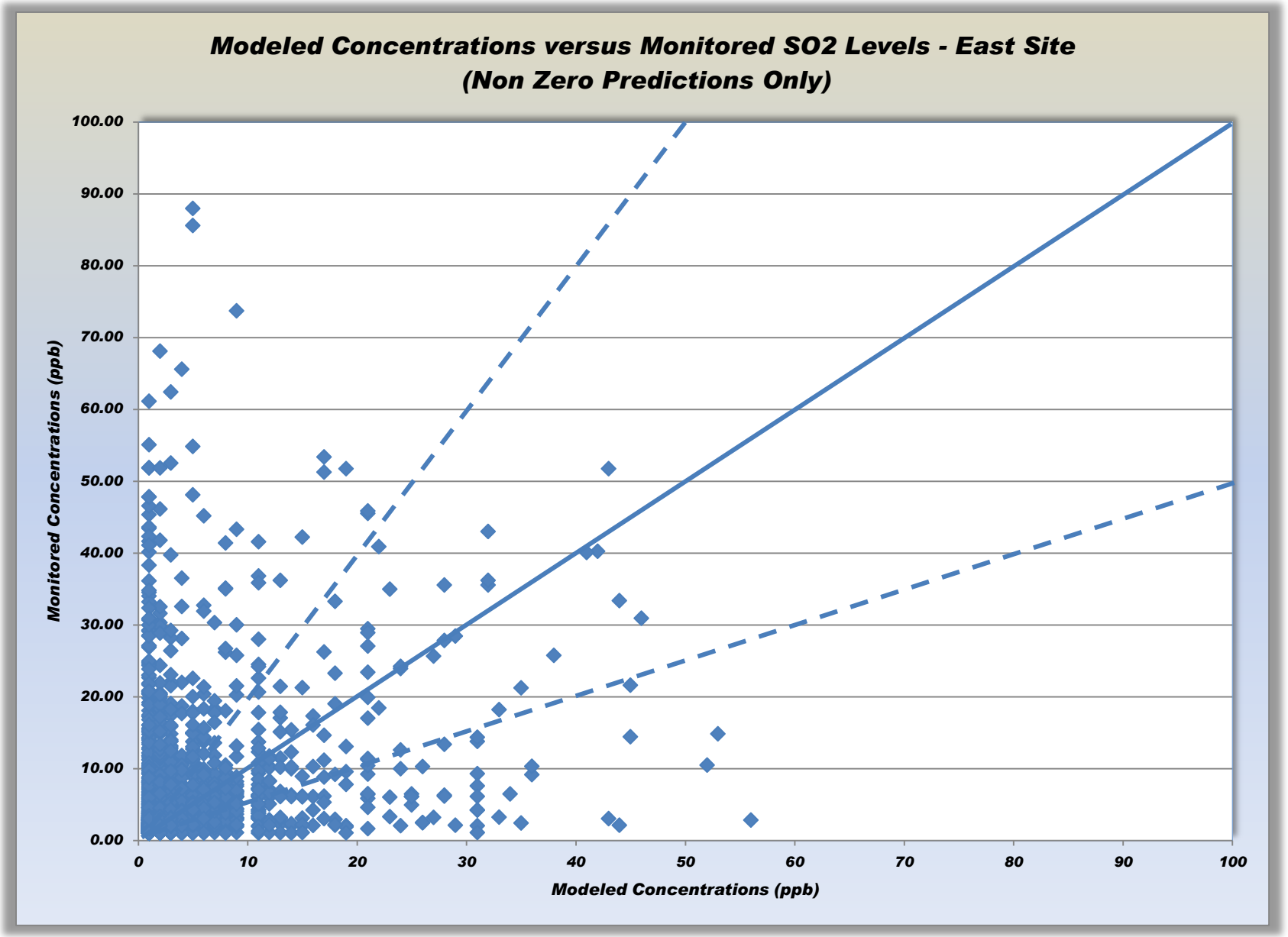

Modeled Concentrations versus Monitored SO2 Levels - East Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
40
50
60
70
80
90
100
Modeled Concentrations (ppb)

Figure 12

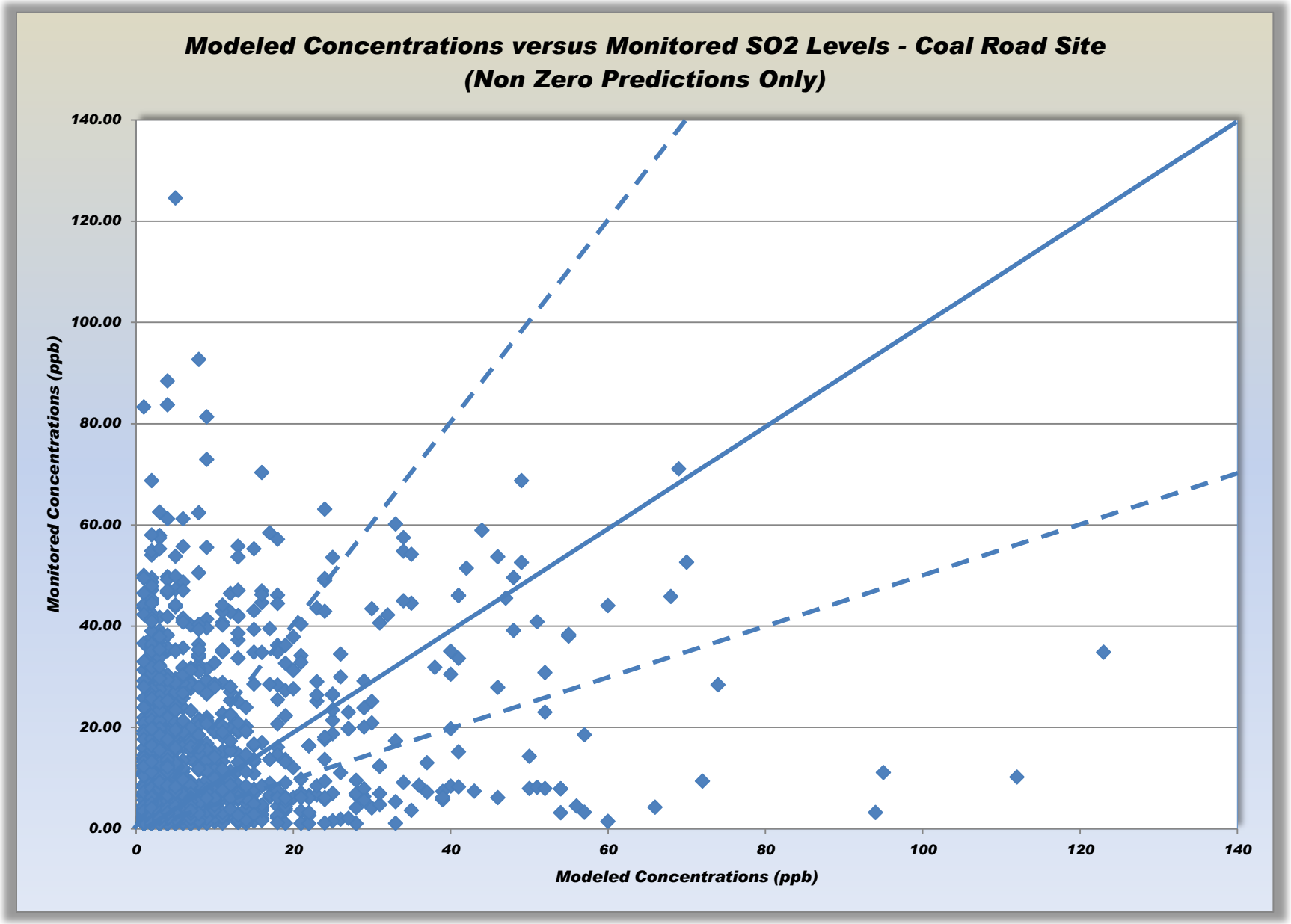
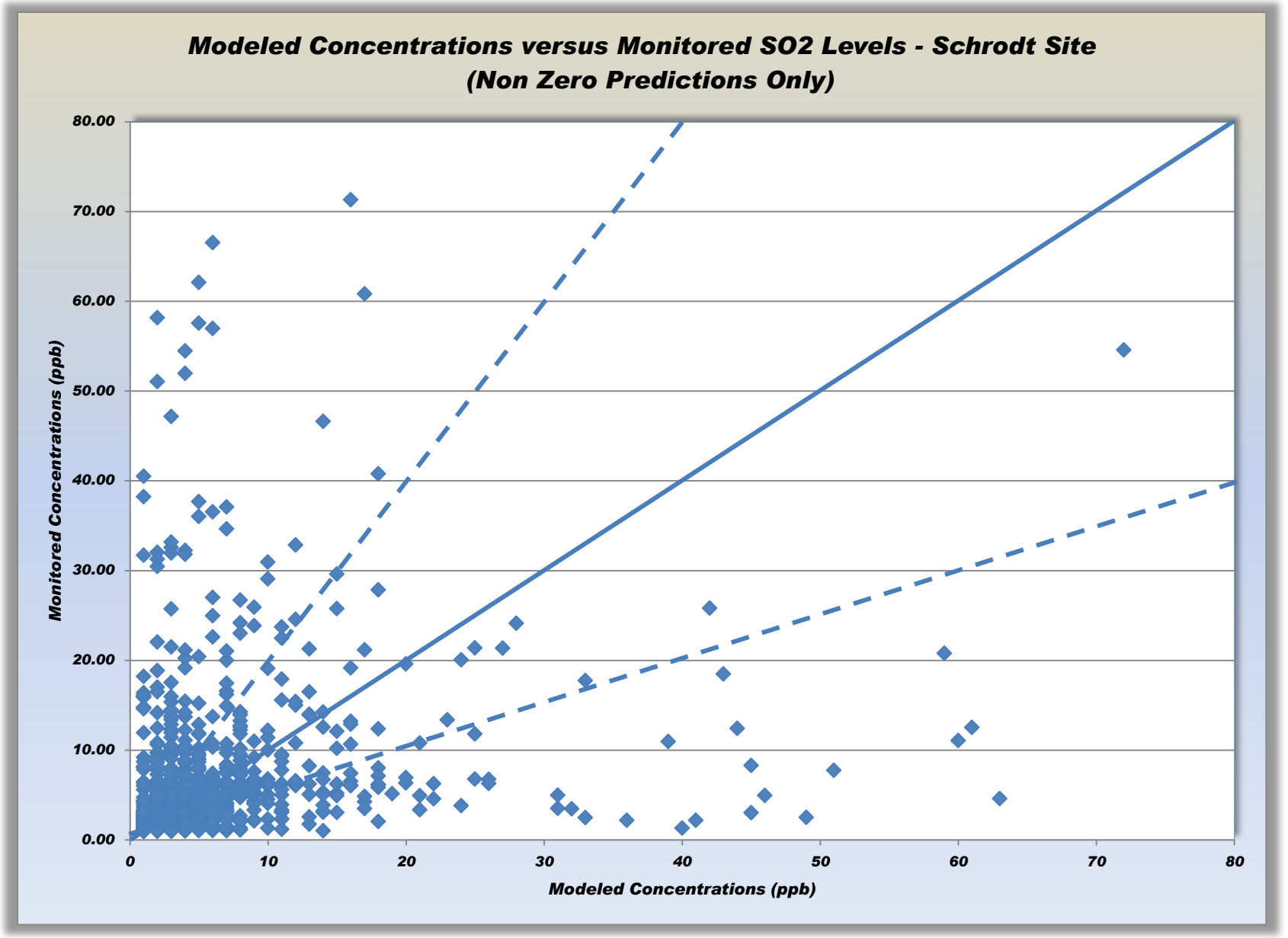

Modeled Concentrations versus Monitored SO2 Levels - Coal Road Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
20
40
60
80
100
120
140
Modeled Concentrations (ppb)

Figure 13


Modeled Concentrations versus Monitored SO2 Levels - Schrodt Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
40
50
60
70
80
Modeled Concentrations (ppb)

Wind Speed Analysis

Table 8 shows the average ratio of modeled divided by monitored concentrations versus wind speed. Three of the four sites, Mt. Carmel, East and Schrodt, show that ratios drop off with speed. The Coal Road shows this trend, but then shows ratios increase as wind speeds increase from about 8 meters per second and above. Remembering that not all wind speed categories may help to explain this difference.

Table 8
Comparison of Average Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	7.89	7.45	4.21	3.31
1.01 – 2	3.50	4.03	3.22	1.98
2.01 – 3	3.74	2.93	1.68	1.32
3.01 – 4	2.82	2.25	1.60	0.94
4.01 – 5	2.01	1.39	2.04	0.80
5.01 – 6	1.91	1.52	1.68	0.83
6.01 – 7	1.79	1.23	2.09	0.87
7.01 – 8	1.22	0.91	1.66	0.83
8.01 – 9	0.99	0.91	2.21	0.75
9.01 – 10	0.95	0.97	2.40	0.74
➢ 10	1.02	0.85	4.29	0.94

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 9 shows the median ratios versus wind speed. The trends seen in the average ratios appear to be duplicated in the median data.

Table 9
Comparison of Median Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	3.17	4.54	2.98	1.74
1.01 – 2	1.75	2.28	1.33	1.25
2.01 – 3	1.31	1.33	0.94	0.86
3.01 – 4	1.15	1.11	0.77	0.73
4.01 – 5	1.08	1.03	0.69	0.75
5.01 – 6	1.05	1.03	0.67	1.00
6.01 – 7	1.06	1.03	0.67	1.01
7.01 – 8	1.04	1.03	0.76	1.02
8.01 – 9	1.03	1.02	0.92	0.88
9.01 – 10	1.03	1.04	1.06	0.84
➢ 10	1.02	1.02	2.95	1.01

Wind Direction Analysis

Table 10 compares average modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 10
Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.14	1.10	0.76	0.83
11 – 20	1.16	1.15	0.81	0.88
21 – 30	1.18	1.37	0.78	0.83
31 – 40	1.35	1.21	0.88	0.77
41 – 50	1.50	2.05	1.42	0.79
51 – 60	0.94	1.09	0.75	0.80
61 – 70	1.18	1.45	0.98	1.89
71 – 80	1.37	1.52	1.05	1.70
81 – 90	1.40	1.65	0.94	**4.39**
91 – 100	1.34	1.63	1.02	3.24
101 – 110	1.16	1.48	0.88	2.62
111 – 120	1.16	1.50	0.96	1.84
121 – 130	1.16	1.63	1.08	1.00
131 – 140	1.05	1.21	0.77	0.88
141 – 150	2.95	1.34	0.90	0.84
151 – 160	5.01	2.22	1.21	0.86
161 – 170	**8.25**	1.54	0.83	0.81
171 – 180	**13.07**	1.37	0.94	0.85
181 – 190	5.25	1.24	1.10	0.85
191 – 200	2.92	1.31	1.79	0.89
201 – 210	1.45	1.16	2.69	0.86
211 – 220	1.45	1.48	**5.67**	0.83
221 – 230	1.40	1.52	5.32	0.86
231 – 240	1.41	1.55	4.53	0.77
241 – 250	1.63	1.90	2.37	0.95
251 – 260	1.22	1.55	0.92	0.82
261 – 270	1.27	1.90	0.74	0.88
271 – 280	1.34	3.46	0.89	0.86
281 – 290	1.44	5.30	0.87	0.90
291 – 300	1.40	**4.80**	0.81	0.90
301 – 310	1.27	**5.08**	0.92	0.87
311 – 320	1.16	5.22	0.79	0.81
321 – 330	1.30	4.15	0.81	0.79
331 – 340	1.49	2.05	0.96	0.94
341 – 350	1.42	1.36	0.87	0.87
351 – 360	1.11	0.97	0.74	0.90

For the key wind directions the average ratios are much higher than two. This indicates that when the wind is blowing from the stacks to the monitors the disagreement between the model and the monitor is greater.

Table 11
Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.06	1.03	0.69	0.84
11 – 20	1.05	1.01	0.64	1.01
21 – 30	1.10	1.07	0.70	0.78
31 – 40	1.15	1.09	0.79	0.57
41 – 50	1.05	1.07	0.85	0.63
51 – 60	0.88	0.86	0.60	0.64
61 – 70	1.05	1.00	0.77	0.85
71 – 80	1.03	1.01	0.87	1.01
81 – 90	1.09	1.16	0.77	1.91
91 – 100	1.13	1.25	0.85	1.70
101 – 110	1.03	1.15	0.75	1.58
111 – 120	1.01	1.04	0.78	0.75
121 – 130	1.03	1.03	0.80	0.70
131 – 140	1.03	1.05	0.70	0.76
141 – 150	1.79	1.08	0.82	0.87
151 – 160	1.79	1.16	0.90	1.00
161 – 170	2.50	1.08	0.75	0.83
171 – 180	4.29	1.11	0.67	1.00
181 – 190	1.94	1.09	0.67	1.00
191 – 200	1.19	1.04	0.90	1.01
201 – 210	1.05	1.05	1.13	1.01
211 – 220	1.13	1.12	2.32	0.78
221 – 230	1.15	1.15	2.47	1.01
231 – 240	1.21	1.23	2.31	0.62
241 – 250	1.19	1.21	1.02	1.00
251 – 260	1.07	1.09	0.66	0.77
261 – 270	1.07	1.00	0.61	0.78
271 – 280	1.07	1.13	0.67	0.67
281 – 290	1.07	1.08	0.64	0.75
291 – 300	1.07	1.02	0.69	0.76
301 – 310	1.03	1.29	0.68	0.81
311 – 320	1.05	1.17	0.67	0.97
321 – 330	1.14	1.38	0.64	0.80
331 – 340	1.11	1.12	0.67	1.01
341 – 350	1.10	1.06	0.62	1.01
351 – 360	1.06	0.92	0.68	1.01

Table 11 shows the median ratios of modeled to monitored concentrations versus wind direction. Once again the key wind directions show the largest discrepancies between the modeled and monitored concentrations. One question that will be addressed later is why are there predicted non-zero concentrations in directions where the winds are not blowing from the stack to the monitors?

A good example of this occurs on January 31, hour 13. The wind direction for this hour is 196 which should take the plume between the Mt. Carmel and Coal Road monitors. However, the following concentrations are predicted for the four monitors.

Monitoring Site	*Predicted Concentration (ppb)*
Mt. Carmel	35.30
East	41.36
Coal Road	35.12
Schrodt	21.13

It is impossible for AERMOD to accurately be predicting concentrations at each of these four monitors given the wind direction of 196. The wind speed for this hour is 0.62 meters per second. As shown later with on-site meteorology, AERMOD seems to be "blowing up" for many cases where the wind speed is less than 1 meter per second and predicting concentrations at all receptors regardless of wind direction. This is an area that U.S. EPA should investigate further.

Comparisons Not in Time

Figures 14 – 17 show predicted concentrations versus monitored concentrations where the values have independently been ranked from lowest to highest. Figure 14 (Mt. Carmel) shows a good agreement by AERMOD. Figure 15 (East) shows good agreement by AERMOD. Figure 16 (Coal Road) shows good agreement by AERMOD. Figure 17 (Schrodt) shows good agreement by AERMOD.

When compared in this fashion, the following overall statistics (ratios of modeled to monitored concentrations) are found:

Ratio	*Mt. Carmel*		*East*		*Coal Road*		*Schrodt*		*Total*	
Range	*Hours*	*Percent*	*Hours*	*Percent*	*Hours*	*Percent*	*Hours*	*Percent*	*Hours*	*Percent*
< 0.5	0	0	0	0	0	0	0	0	0	0
0.5 – 2	3146	92.5	3253	100	3278	94.2	3455	100	13132	96.6
➢ 2.0	256	7.5	0	0	203	5.8	0	0	459	3.4
Total	3402		3253		3481		3455		13591	

This appears to show good agreement between AERMOD and the monitored values.

Figure 14

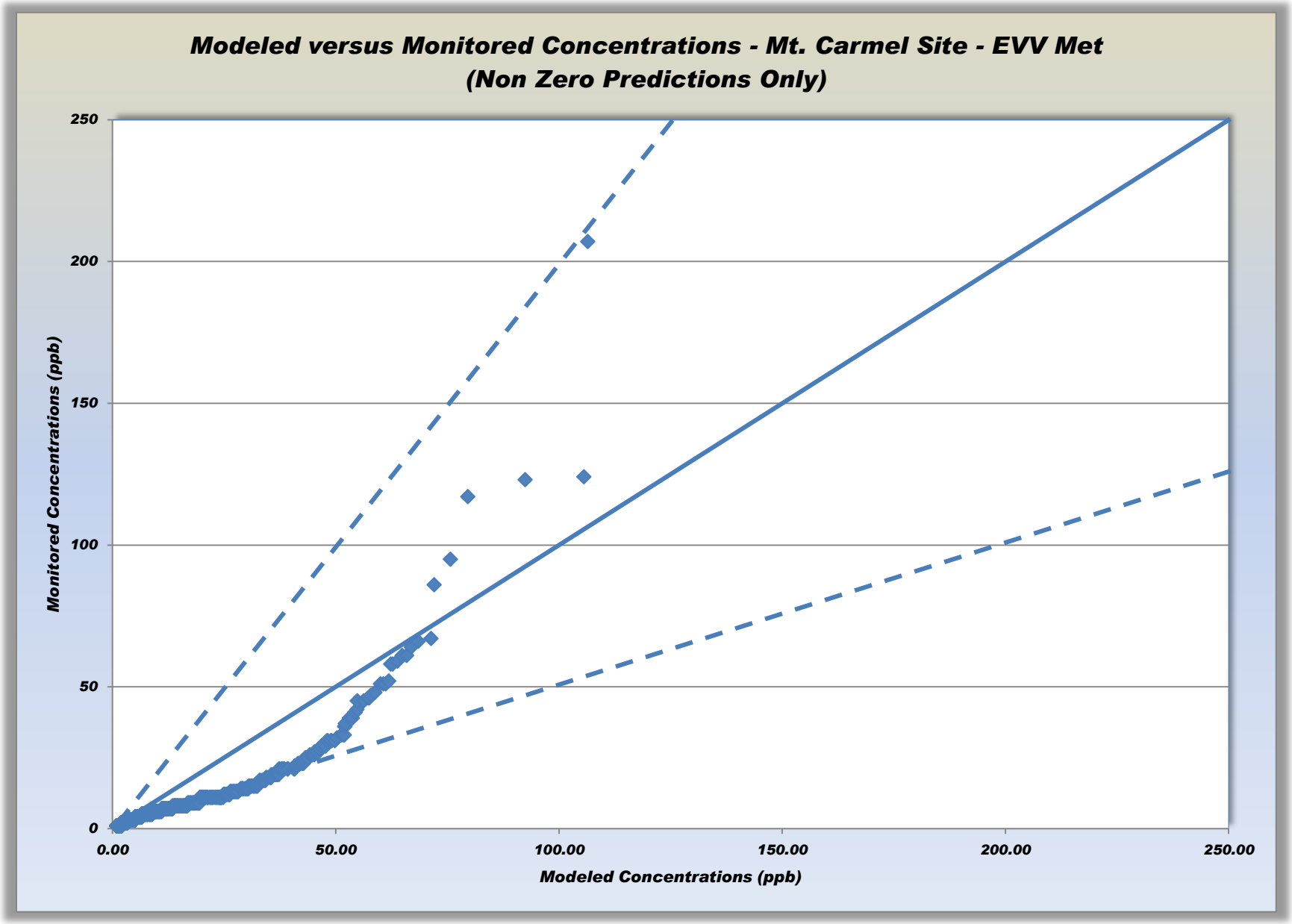

Modeled versus Monitored Concentrations - Mt. Carmel Site - EVV Met
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
250
200
150
100
50
0
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

Figure 15

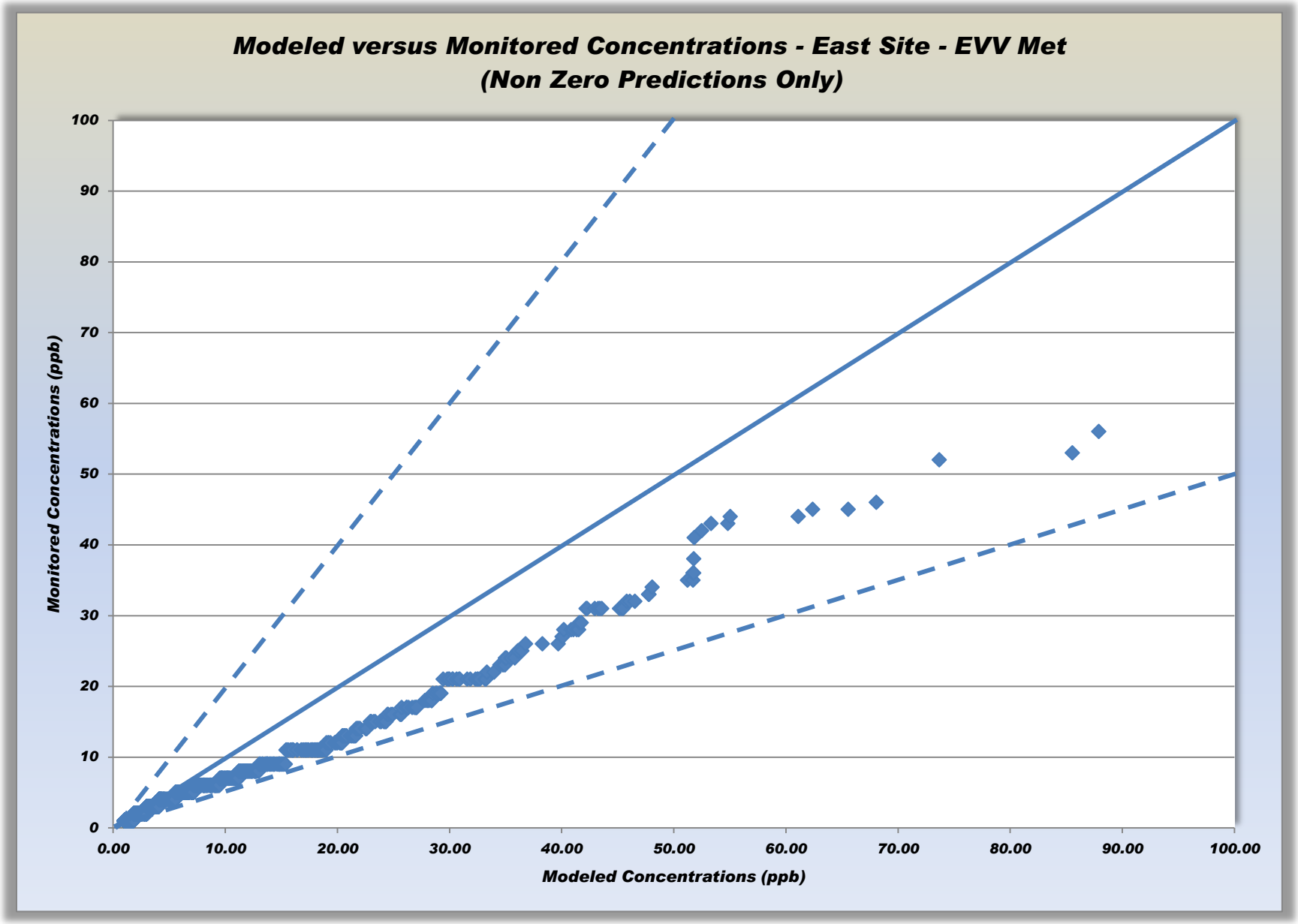

Modeled versus Monitored Concentrations - East Site - EVV Met
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
100
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

Figure 16

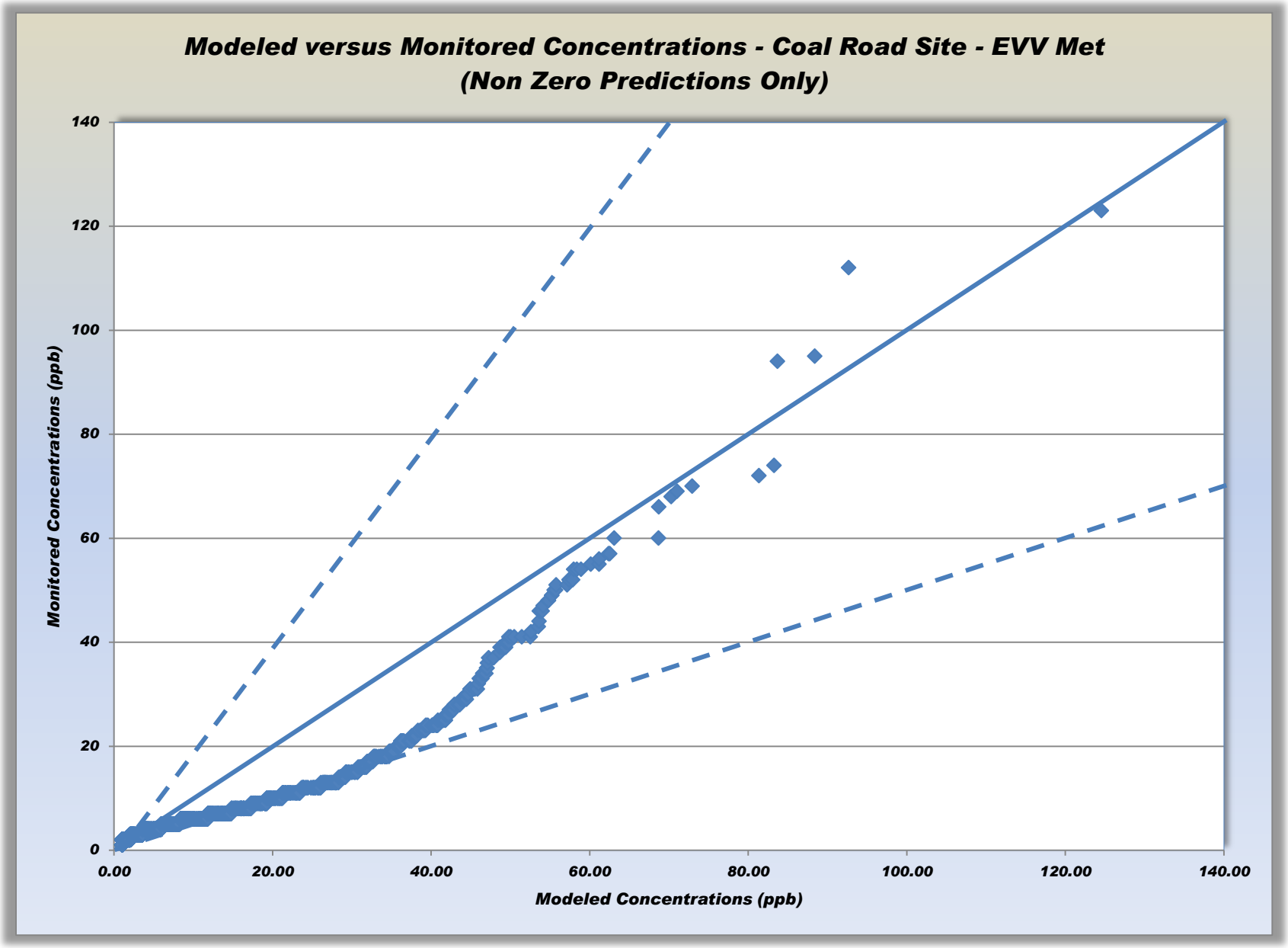

Modeled versus Monitored Concentrations - Coal Road Site - EVV Met
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Figure 17

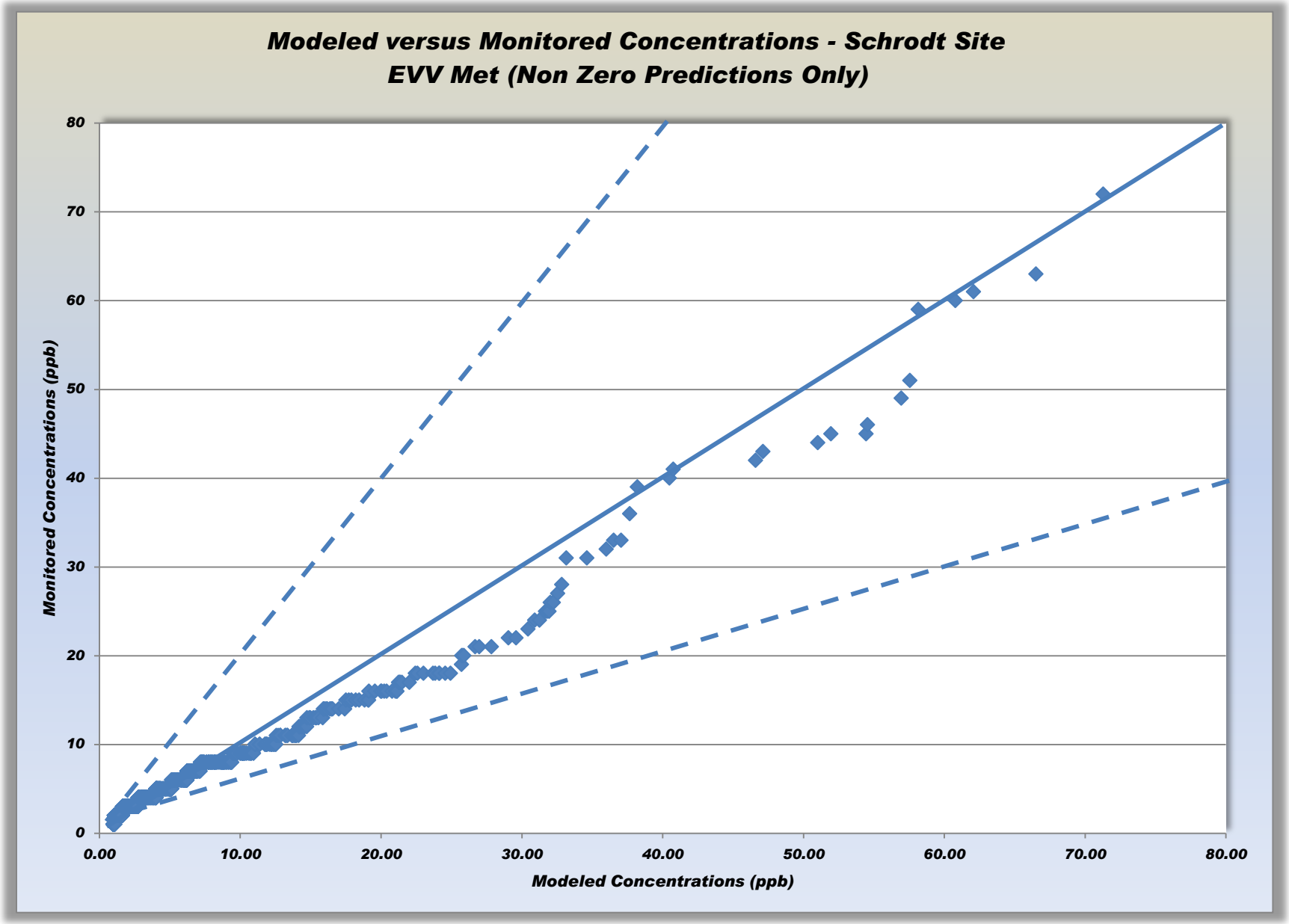

Modeled versus Monitored Concentrations - Schrodt Site
EVV Met (Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

Table 12 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the numbers of hours that exceed the standard of 35 ppb. Overall AERMOD predicts 13 hours above the standard while the monitors measured 11.

Table 12
Hours within Selected Ranges – Scenario 2 – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt	
Range	**Model**	**Monitor**	**Model**	**Monitor**	**Model**	**Monitor**	**Model**	**Monitor**
1 – 25	3228	3345	3153	3209	3203	3386	3414	3429
26 – 50	136	39	83	41	236	70	30	20
51 – 75	33	12	15	3	36	21	11	6
76 – 100	3	2	2	0	5	2	0	0
101 – 125	2	2	0	0	1	2	0	0
126 – 150	0	0	0	0	0	0	0	0
151 – 175	0	0	0	0	0	0	0	0
176 – 200	0	0	0	0	0	0	0	0
201 – 225	0	1	0	0	0	0	0	0
Total	3402	3402	3253	3253	3481	3481	3455	3455
Above 75	5	5	2	0	6	4	0	0

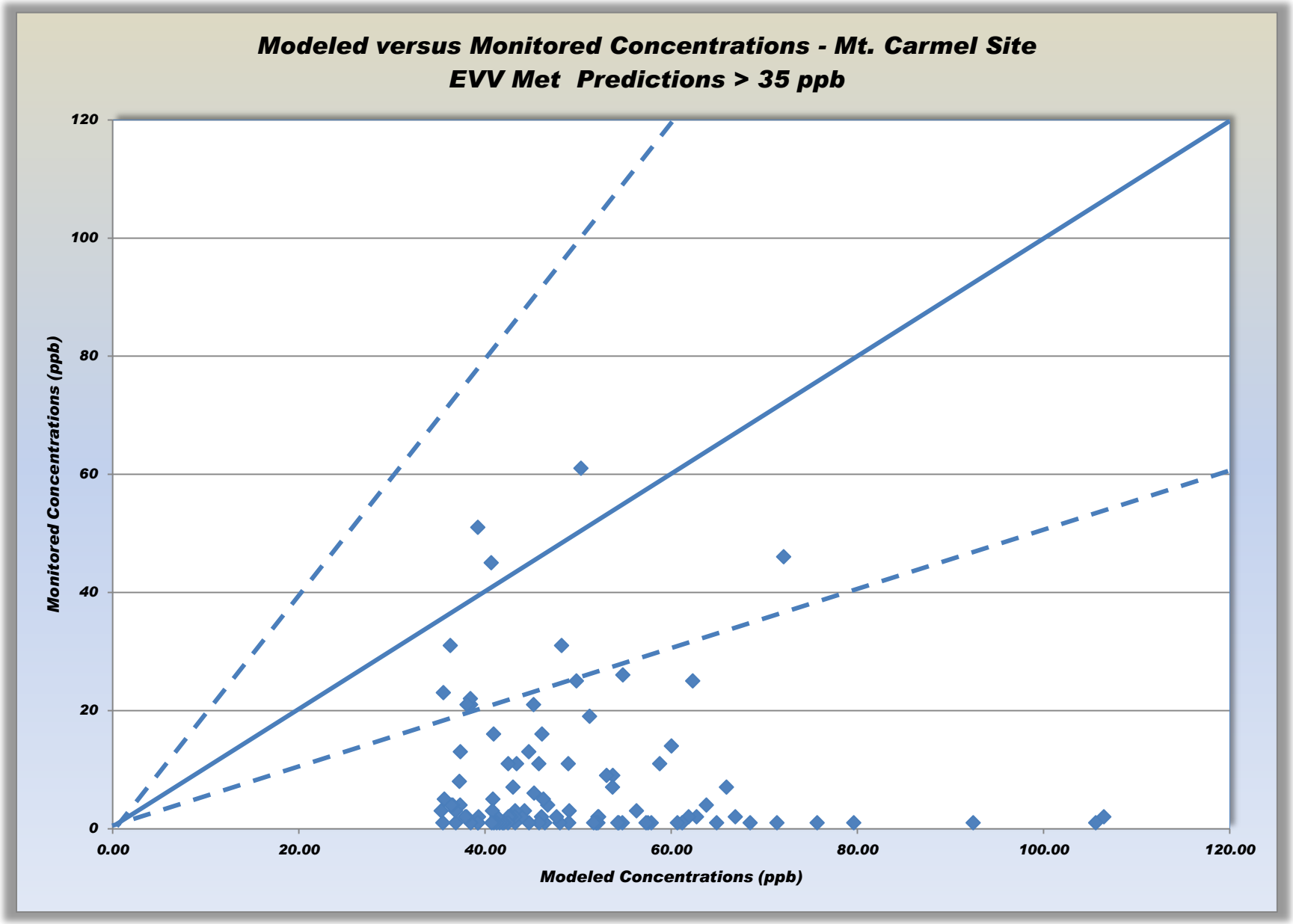
Predictions Greater Than 35 parts per billion (ppb)

Even when looking at non-zero predicted hours, the majority of the concentrations are in the range of 1 to 10 ppb. This range is of little interest in the regulatory scheme. When the model predicts concentrations at or above 35 ppb, approximately half the level of the national ambient air quality standard for SO2, model performance is much more of an issue. This section focuses on predicted SO2 concentrations that are 35 ppb or greater.

Mt. Carmel Site

Figure 18 shows a comparison of modeled and monitored SO2 concentrations for the Mt. Carmel site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 102 hours of ratios (modeled to monitored) shown, eleven are within the factor of two range (10.8 percent) while 91 hours are above a factor of two (89.2 percent).

Figure 18


Modeled versus Monitored Concentrations - Mt. Carmel Site
EVV Met Predictions > 35 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
0.00
20.00
40.00
60.00
80.00
100.00
120.00

East Site

Figure 19 shows a comparison of modeled and monitored SO2 concentrations for the East site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 52 hours of ratios (modeled to monitored) shown, eight are within the factor of two range (15.4 percent) while 44 hours are above a factor of two (84.6 percent).

Coal Road Site

Figure 20 shows a comparison of modeled and monitored SO2 concentrations for the Coal Rd. site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 151 hours of ratios (modeled to monitored) shown, 32 are within the factor of two range (21.2 percent) while 119 hours are above a factor of two (78.8 percent).

Schrodt Site

Figure 21 shows a comparison of modeled and monitored SO2 concentrations for the Schrodt site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 20 hours of ratios (modeled to monitored) shown, 1 is within the factor of two range (5.0 percent) while 19 hours are above a factor of two (95.0 percent).

Overall this indicates that AERMOD is over-predicting 84 percent of the predicted concentrations that are 35 ppb or greater. In no case is it under-predicting these concentrations. In only 16 percent of the cases are the predictions within a factor of two. This would indicate problems with the model, both in accuracy and over-prediction.

Comparisons Not In Time

Adjustment to Emission Rates

In comparing hours without comparing them in time, there is a problem that the predicted concentrations are based on different emission rates than those seen on the monitored days. In an attempt to correct for this, the emission rate on the highest monitored hour was determined as well as the emission rate on the highest predicted hour. The predicted concentration was then adjusted by a ratio of the monitored emission rate divided by the predicted emission rate. This set of corrections was made for all hours where the predicted concentration was greater than 35 ppb. The results for each site as discussed below.

Mt. Carmel Site

Figure 22 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Mt. Carmel Site. Of the 100 hours included, 71 are within a factor of two of the monitored values, while 28 are over-predicted by more than a factor of two. One of the values is under-predicted.

Figure 19

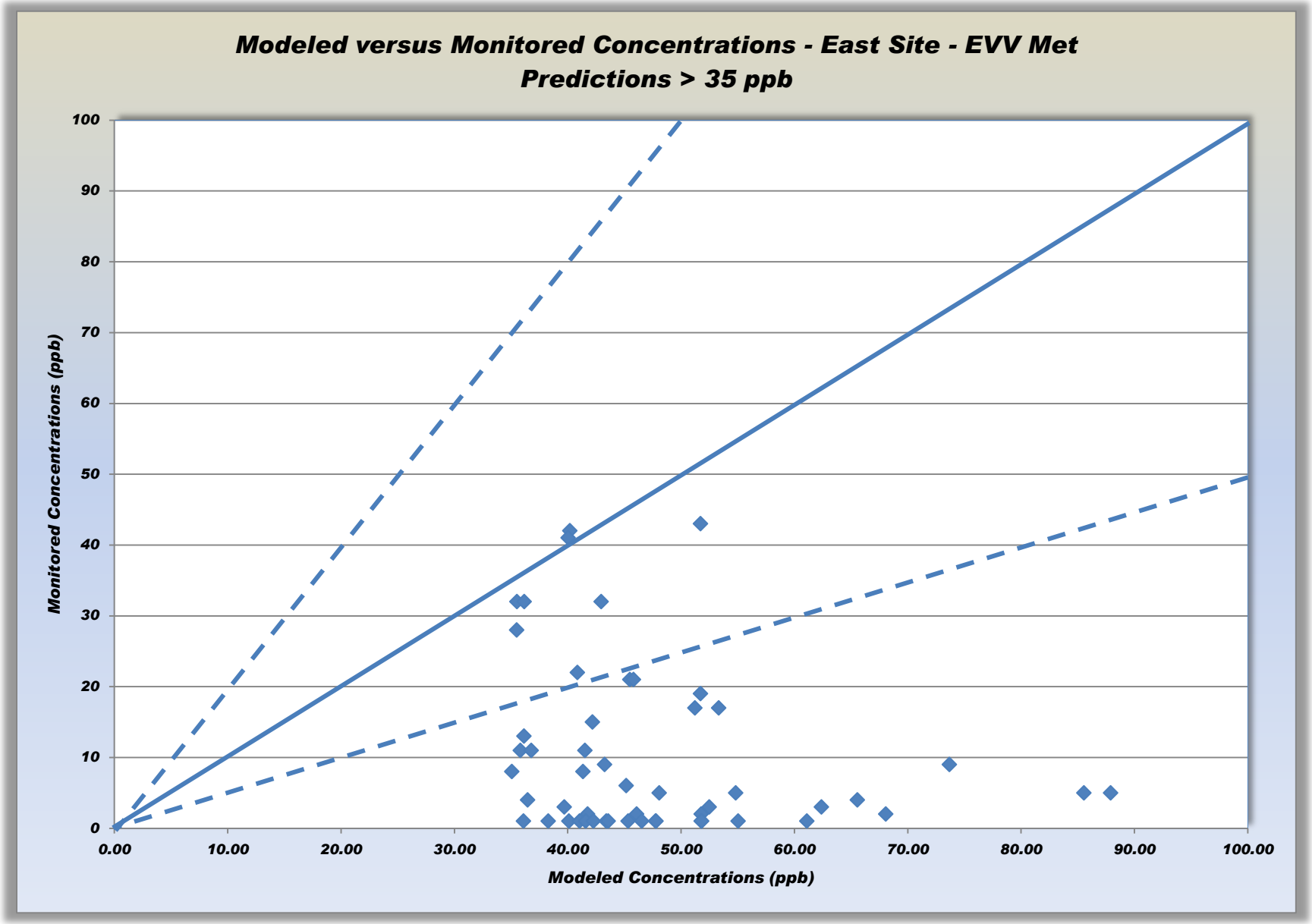

Modeled versus Monitored Concentrations - East Site - EVV Met
Predictions > 35 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
100
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

Figure 20

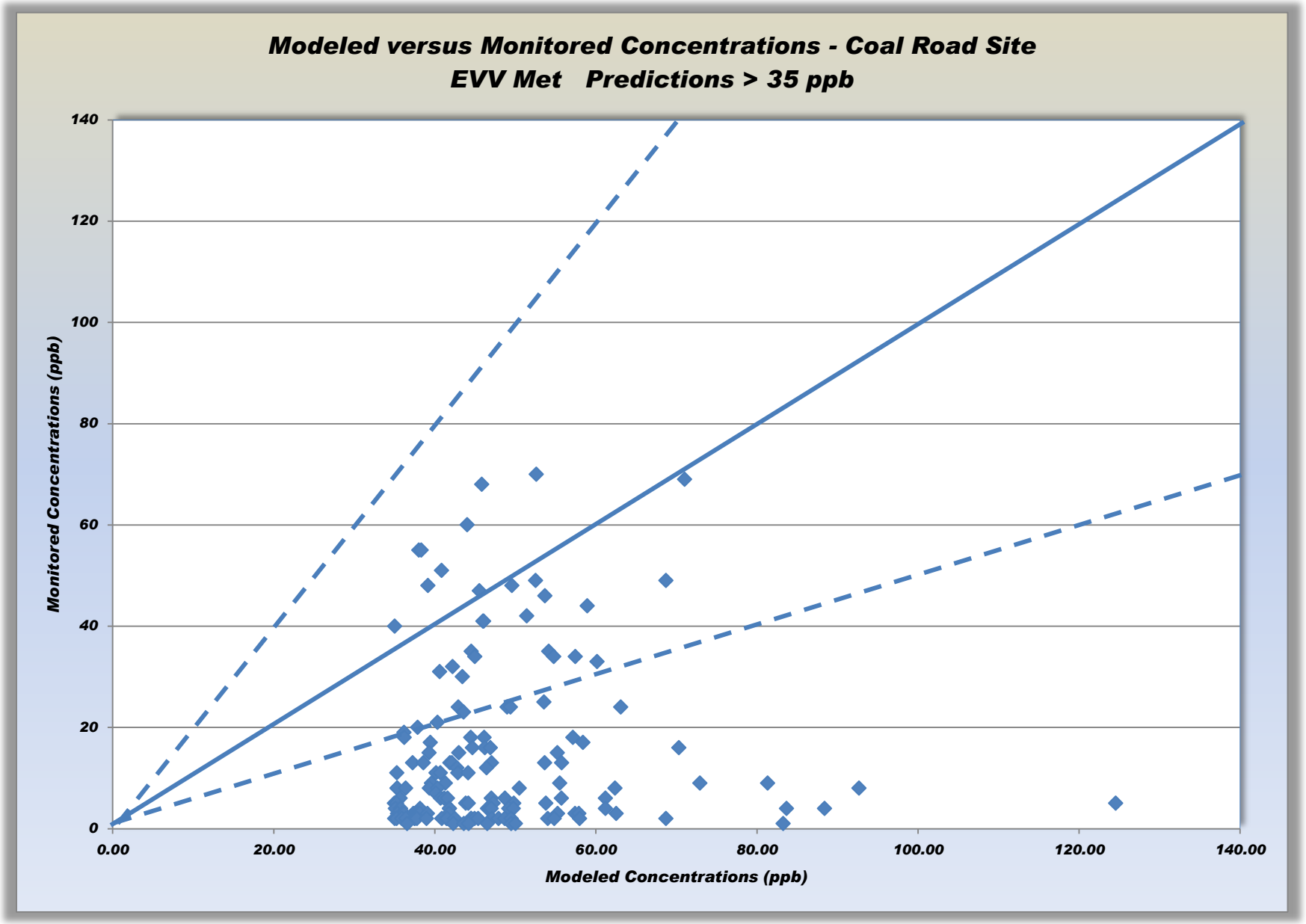

Modeled versus Monitored Concentrations - Coal Road Site
EVV Met Predictions > 35 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Figure 21

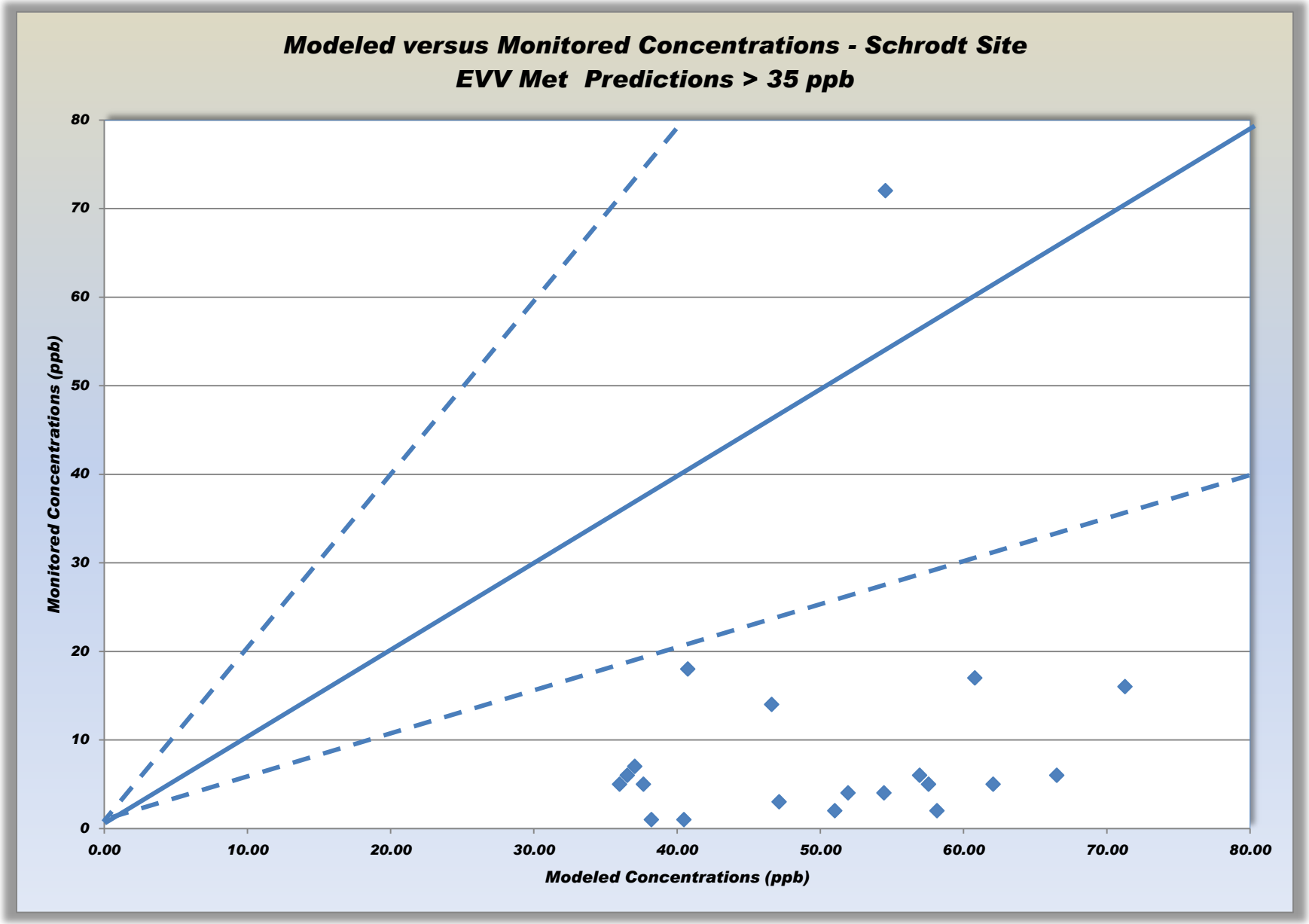

Modeled versus Monitored Concentrations - Schrodt Site
EVV Met Predictions > 35 ppb
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

Figure 22

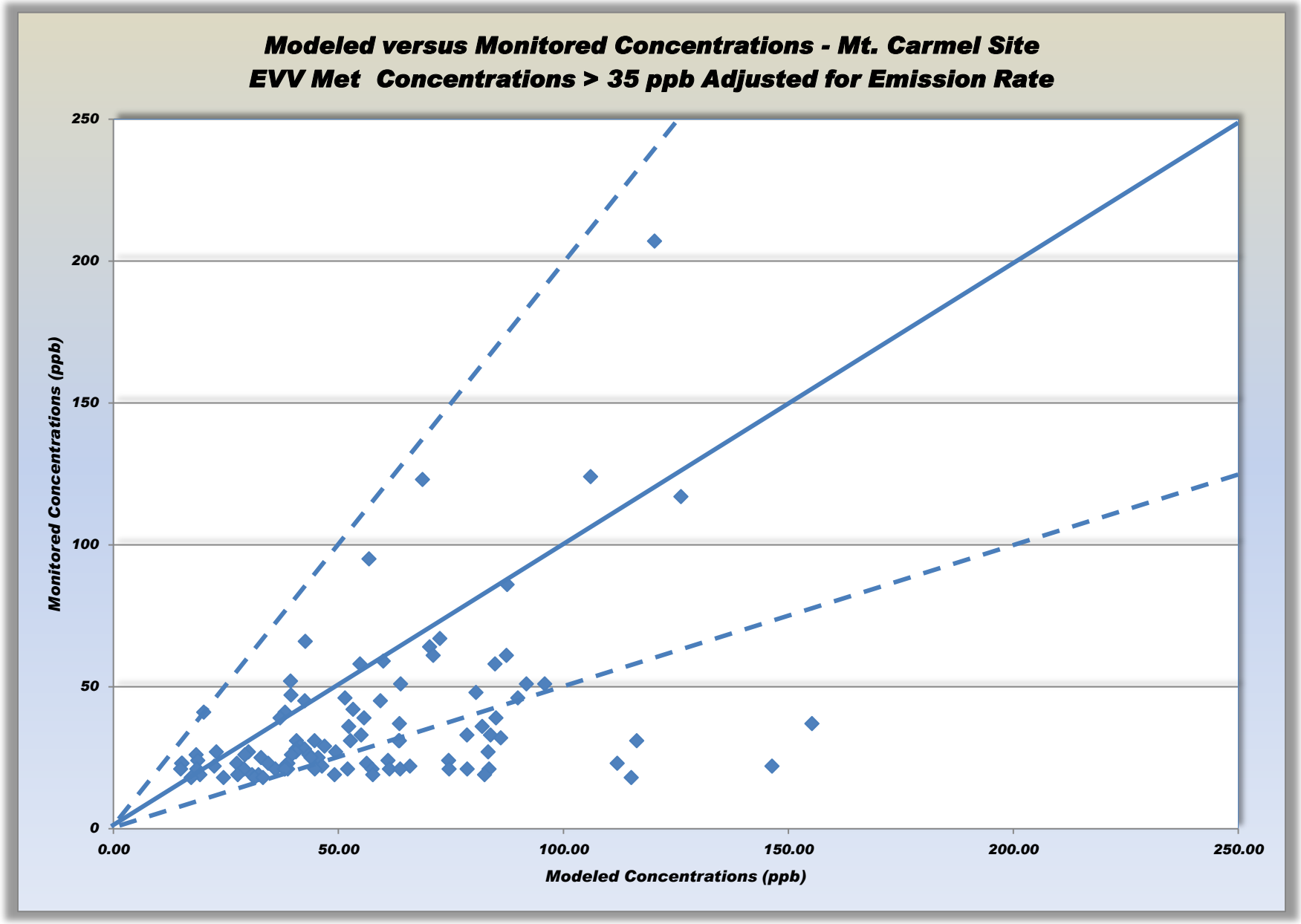
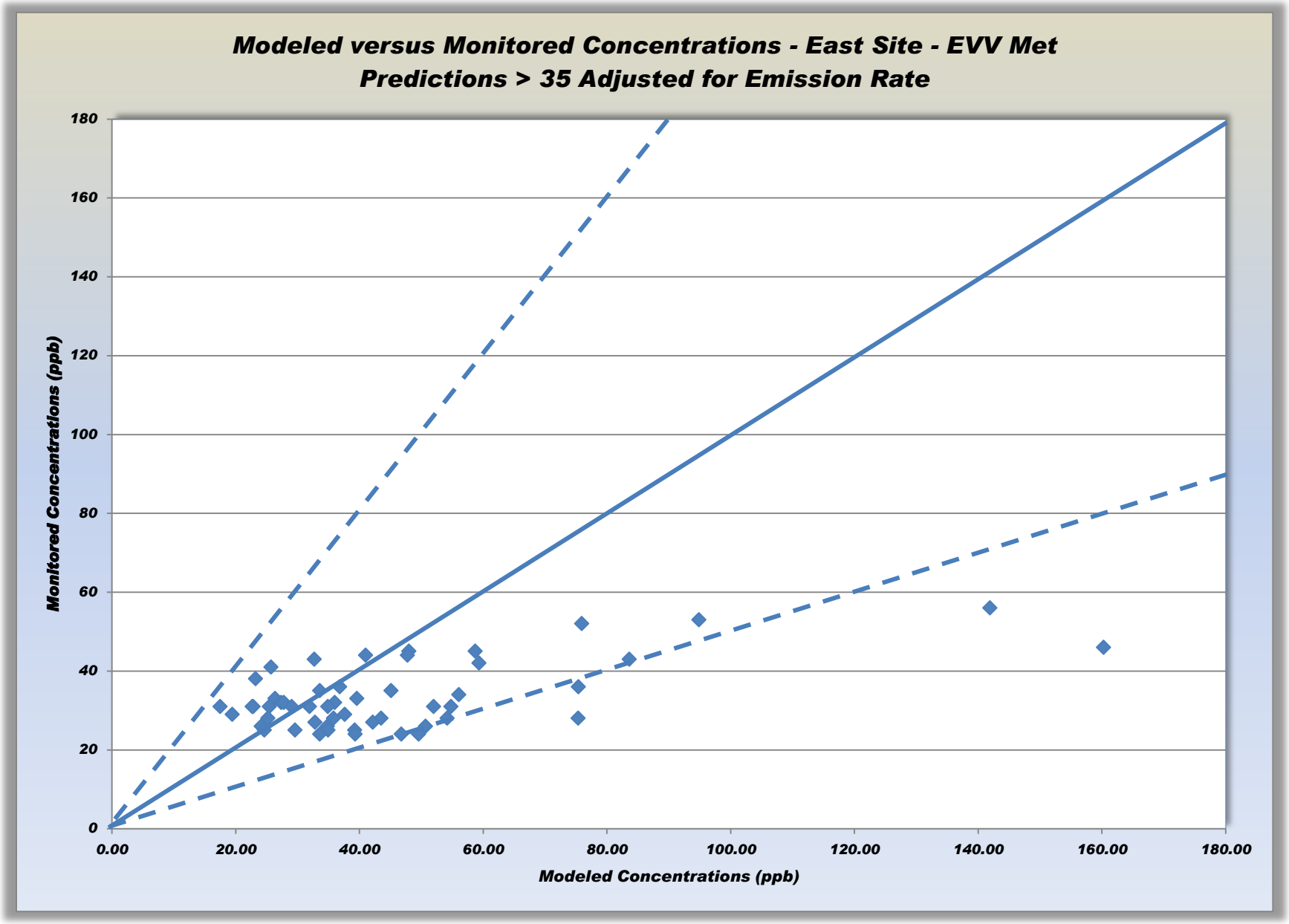

Modeled versus Monitored Concentrations - Mt. Carmel Site
EVV Met Concentrations > 35 ppb Adjusted for Emission Rate
Monitored Concentrations (ppb)
250
200
150
100
50
0
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

Figure 23


Modeled versus Monitored Concentrations - East Site - EVV Met
Predictions > 35 Adjusted for Emission Rate
Monitored Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Modeled Concentrations (ppb)

East Site

Figure 23 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the East Site. Of the 52 hours included, 47 are within a factor of two of the monitored values, while 5 are over-predicted by more than a factor of two. None of the values are under-predicted.

Coal Road Site

Figure 24 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Coal Road Site. Of the 151 hours included, 130 are within a factor of two of the monitored values, while 19 are over-predicted by more than a factor of two. Two of the values are under-predicted.

Schrodt Site

Figure 25 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Schrodt Site. Of the 20 hours included, all 20 are within a factor of two of the monitored values.

SUMMARY

While the emission rate correction improves the agreement between predicted and monitored values, approximately 16 percent of the readings are over-predicted while less than 1 percent is under-predicted.

The U.S. EPA argues that it is inappropriate to compare the values at the monitor sites (predicted and measured) due to the fact that the meteorological data from the National Weather Service station in Evansville may not be correct for the Gibson site. By the time the winds get there they may have different directions, perhaps plus or minus 10 degrees. The wind speeds may be different. While not included in this report, the U.S. EPA suggests looking at other receptor locations surrounding the monitor sites and using the highest predicted values within this box. Using higher predicted values will not improve the agreement between the monitored values and predicted values. It will result in worse model performance. Instead of pursuing this we have looked at the predicted concentrations at the monitor sites using on-site meteorology. This is addressed in the next section.

SCENARIO 3 RESULTS

Scenario 3 involves modeling using on-site data. The on-site meteorological data has been processed in a non-standard way. Typical processing begins with the lowest level of data and then proceeds to fill in missing data with higher levels. In this case to minimize the impact of an on-site cooling pond and due to the fact that the stacks are fairly tall, the data has been processed from the top down. This should provide a better set of meteorological data for the modeling analysis.

Figure 24

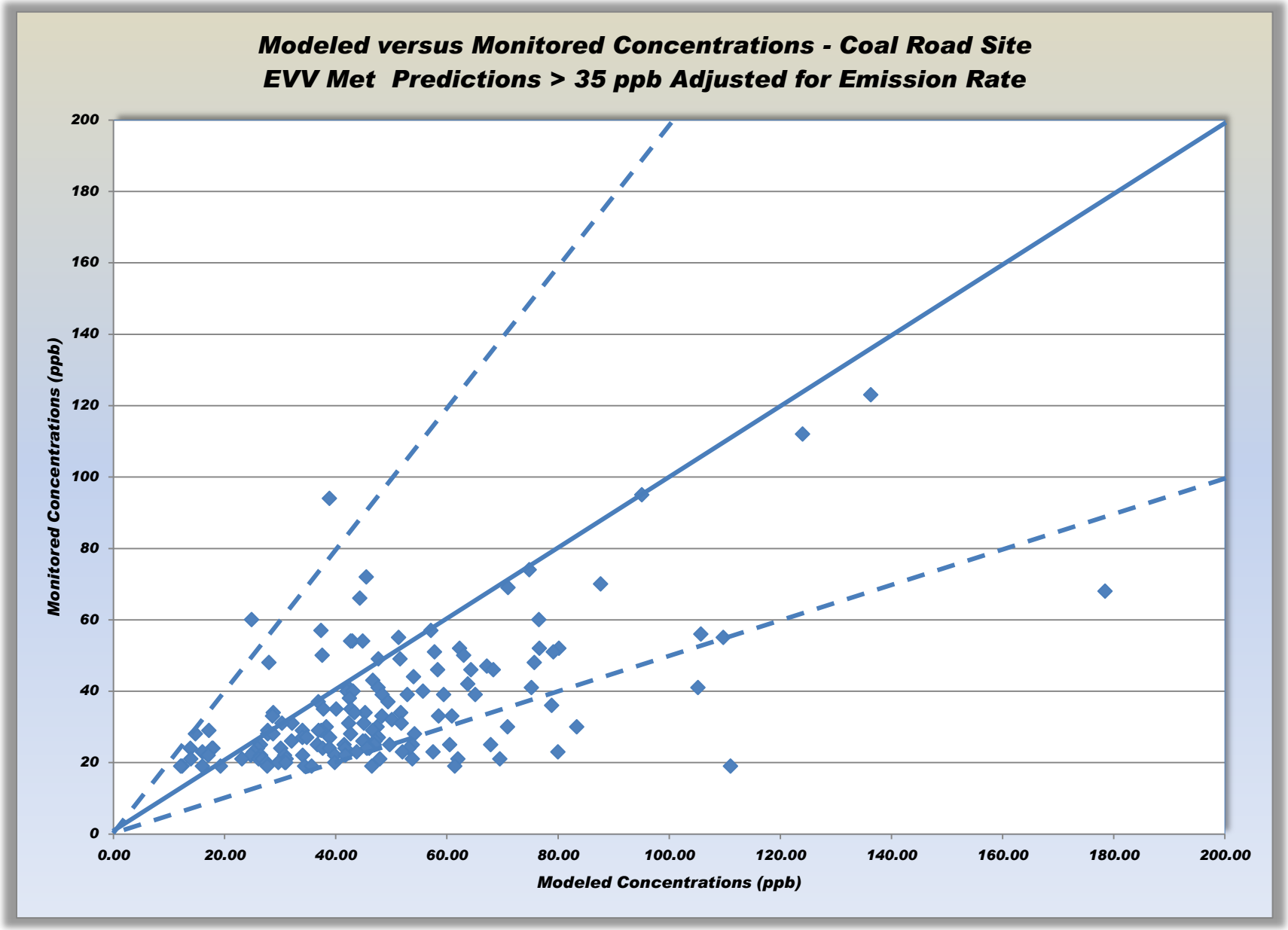
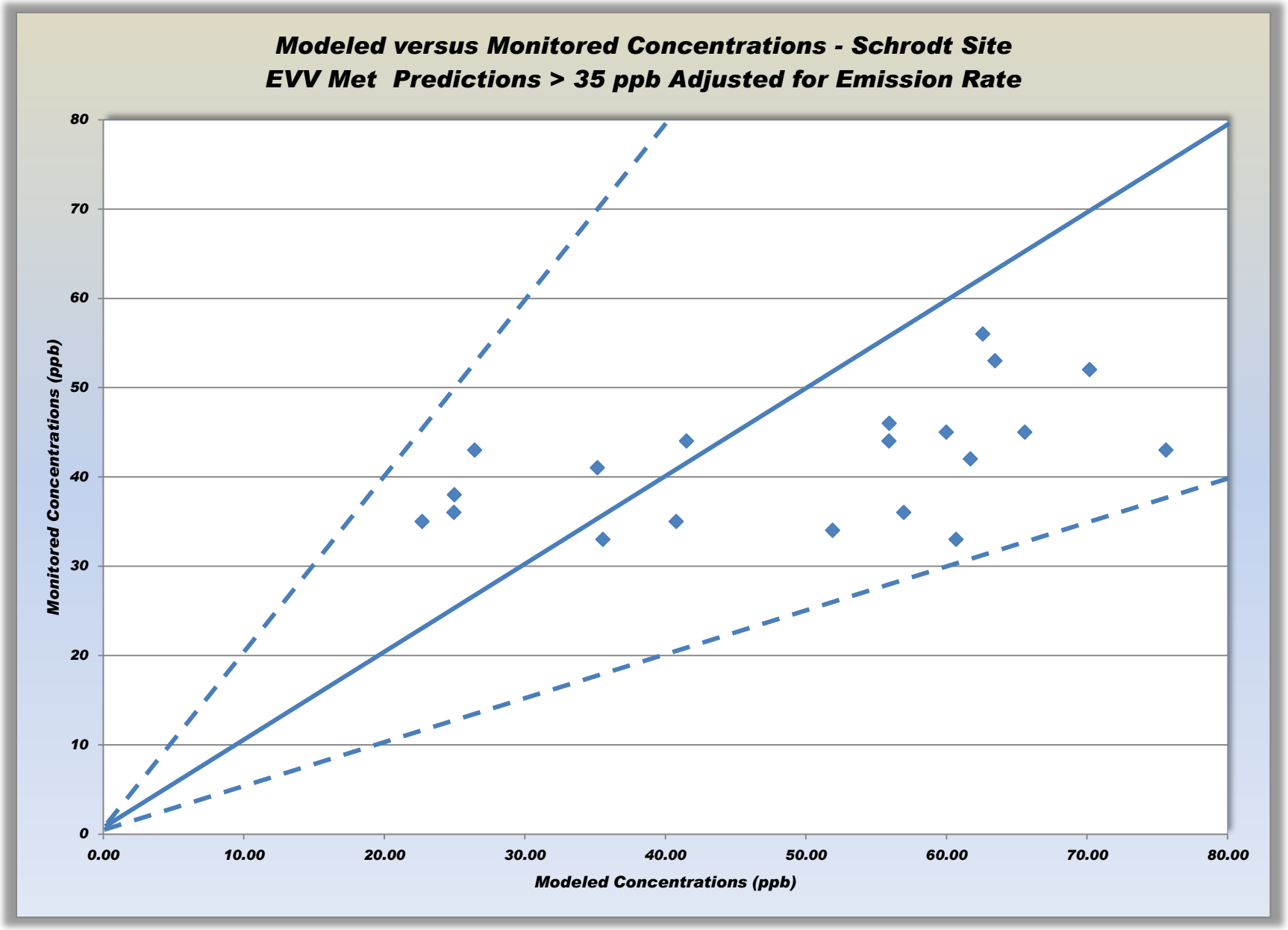

Modeled versus Monitored Concentrations - Coal Road Site
EVV Met Predictions > 35 ppb Adjusted for Emission Rate
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00

Figure 25


Modeled versus Monitored Concentrations - Schrodt Site
EVV Met Predictions > 35 ppb Adjusted for Emission Rate
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

All Data

The first set of results included all data where the hour has both a modeled and a monitored concentration. Those hours where monitored values were missing were excluded from the analysis.

Mt. Carmel Site

Figure 26 shows a comparison of modeled and monitored concentrations compared in time for the Mt. Carmel site. The line from the lower left corner to the upper right corner shows where the model and the monitor would perfectly agree. The other two lines show the factor of 2 areas. Values above the corner to corner line are under-predicted. Values below the corner to corner line are over-predicted. Those contained within the lines are within a factor of 2 of the monitored values. Of the 8,213 hours of data, 87.9 percent are within a factor of 2, 4.3 percent are under-predicted and 7.8 percent are over-predicted.

East Site

Figure 27 shows a comparison of modeled and monitored concentrations compared in time for the East site. Of the 8,360 hours of data, 83.6 percent are predicted within a factor of 2, 9.9 percent are under-predicted and 6.5 percent are over-predicted.

Coal Road Site

Figure 28 shows a comparison of modeled and monitored concentrations compared in time for the Coal Road site. Of the 8,349 hours of data, 75.1 percent are predicted within a factor of 2, 17.6 percent are under-predicted and 7.3 percent are over-predicted.

Schrodt Site

Figure 29 shows a comparison of modeled and monitored concentrations compared in time for the Schrodt site. Of the 8,319 hours of data, 76.4 percent are predicted within a factor of 2, 20.3 percent are under-predicted and 3.3 percent are over-predicted.

SUMMARY

Table 13 summarizes the results for all four sites. Overall 80.8 percent of the predictions are within a factor of 2 of the measured values, 13.0 percent are under-predicted and 6.2 percent are over-predicted. While this appears to be a reasonable performance later sections will explain why it is not.

Figure 26

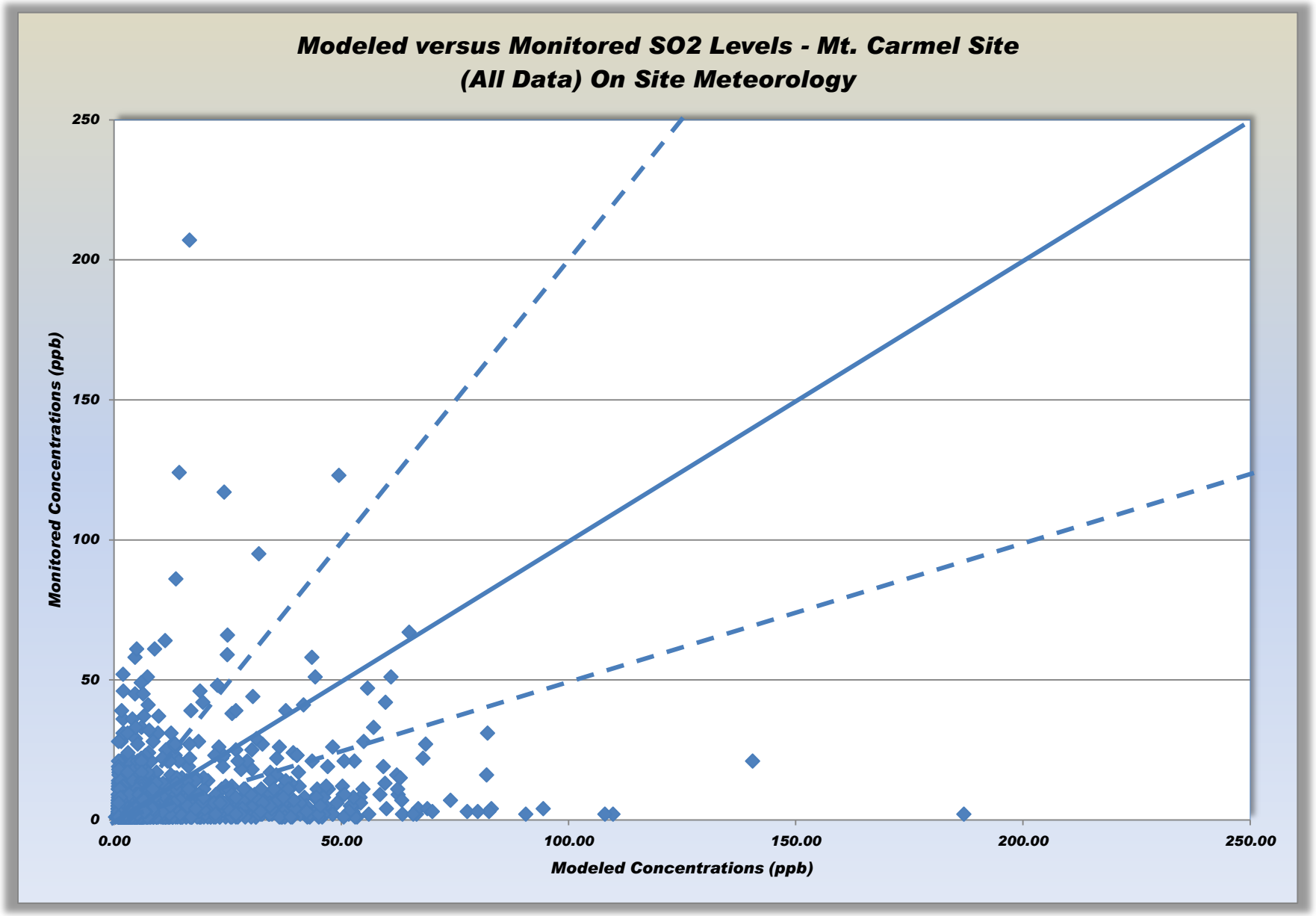

Modeled versus Monitored SO2 Levels - Mt. Carmel Site
(All Data) On Site Meteorology
Monitored Concentrations (ppb)
250
200
150
100
50
0
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

Figure 27

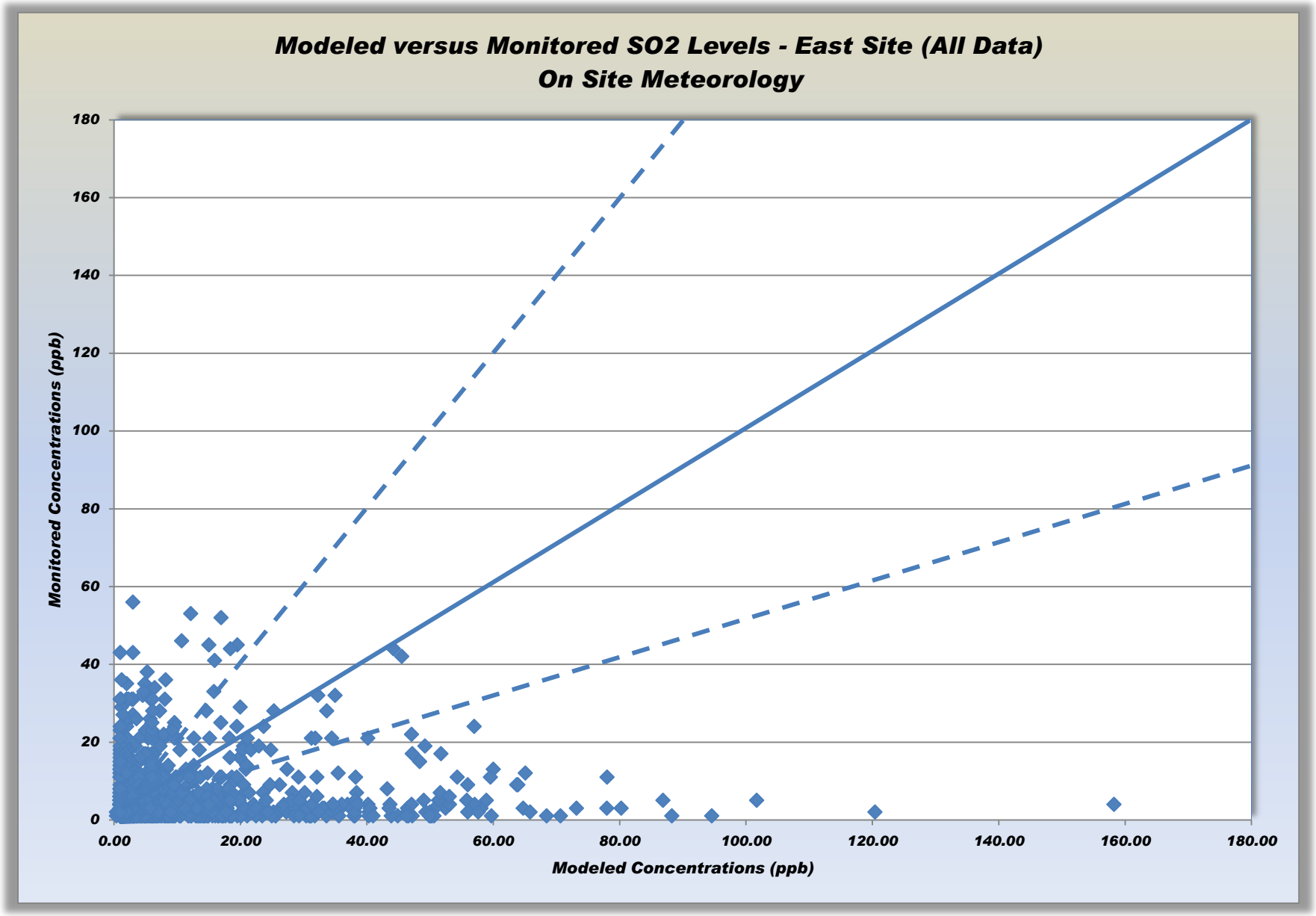

Modeled versus Monitored SO2 Levels - East Site (All Data)
On Site Meteorology
Monitored Concentrations (ppb)
180
160
140
120
100
80
60
40
20
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Modeled Concentrations (ppb)

Figure 28

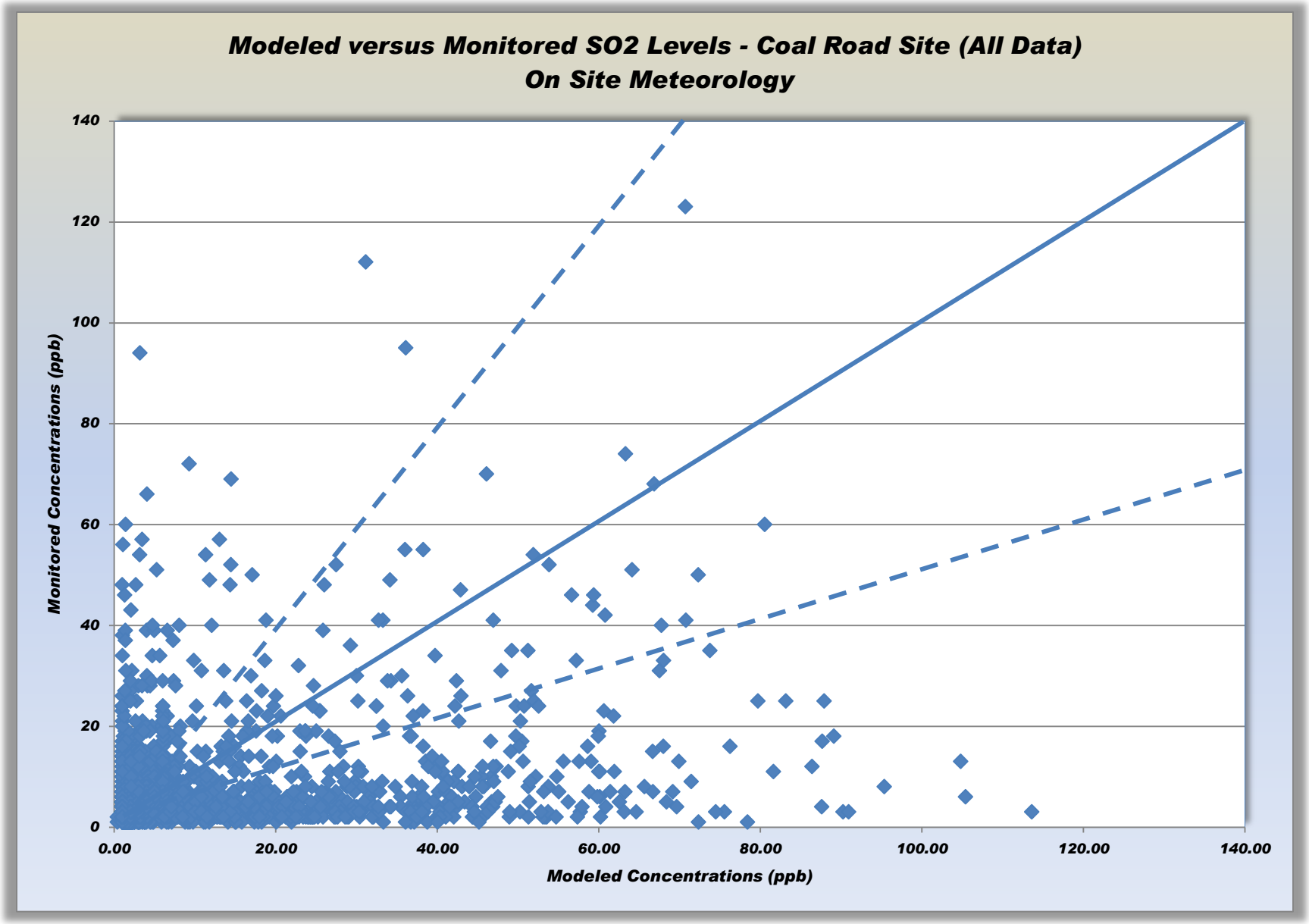

Modeled versus Monitored SO2 Levels - Coal Road Site (All Data)
On Site Meteorology
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Figure 29

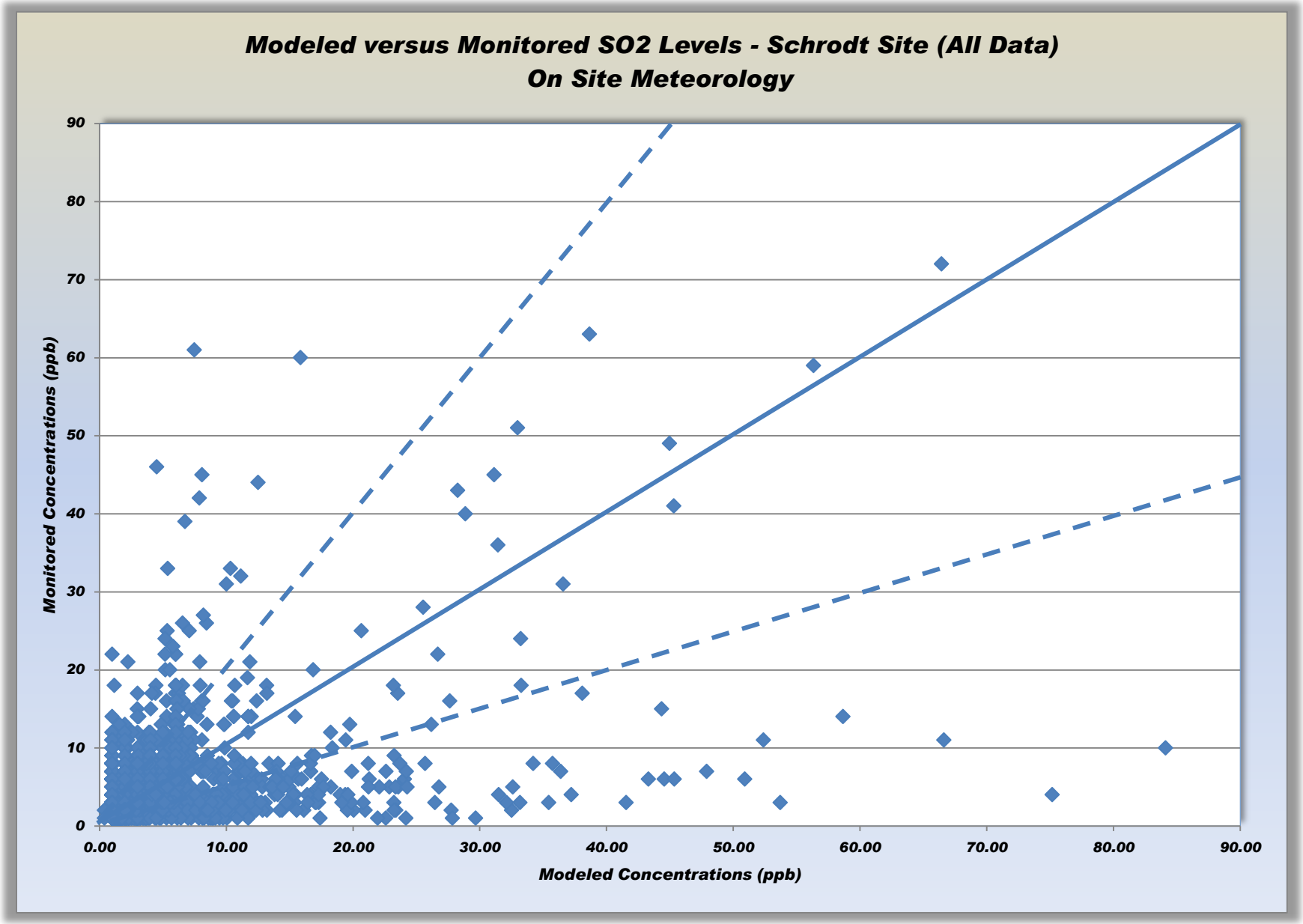

Modeled versus Monitored SO2 Levels - Schrodt Site (All Data)
On Site Meteorology
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

Table 13
Results of Scenario 3 Analyses – All Data

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
<0.5	353	4.3	826	9.9	1470	17.6	1685	20.3	4334	13.0
0.5 – 2.0	7222	87.9	6992	83.6	6267	75.1	6357	76.4	26838	80.8
➢ 2.0	638	7.8	542	6.5	612	7.3	277	3.3	2069	6.2
Total	8213		8360		8349		8319		33241	

Wind Speed Analysis

Table 14 shows the average ratio of modeled divided by monitored concentrations versus wind speed. All four sites show that ratios drop off and then increase with wind speed. Ratios for the lowest and highest wind speeds may not contain nearly as many data points as those for mid-range wind speeds.

Table 14
Comparison of Average Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	4.07	4.79	2.65	2.04
1.01 – 2	2.09	2.27	1.48	1.21
2.01 – 3	1.58	1.46	1.15	0.82
3.01 – 4	1.34	1.15	0.95	0.71
4.01 – 5	1.11	0.92	0.83	0.70
5.01 – 6	1.13	0.87	0.95	0.71
6.01 – 7	1.19	0.87	0.90	0.77
7.01 – 8	1.32	0.92	1.14	0.85
8.01 – 9	1.01	0.89	0.95	0.87
9.01 – 10	1.10	0.87	1.24	0.86
➢ 10	1.28	0.91	1.32	0.82

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 15 shows the median ratios versus wind speed. In all cases the ratios are between 0.5 and 2.

Table 15
Comparison of Median Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	1.00	1.00	0.75	1.00
1.01 – 2	1.00	1.00	0.75	0.80
2.01 – 3	1.00	1.00	0.67	0.67
3.01 – 4	1.00	1.00	0.56	0.60
4.01 – 5	1.00	1.00	0.50	0.63
5.01 – 6	1.00	1.00	0.50	0.67
6.01 – 7	1.00	1.00	0.51	1.00
7.01 – 8	1.00	1.00	0.53	1.00
8.01 – 9	1.00	1.00	0.51	1.00
9.01 – 10	1.00	1.00	0.52	1.00
➢ 10	1.01	1.01	0.51	1.00

Wind Direction Analysis

Table 16 compares modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 16
Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.12	0.96	0.75	0.82
11 – 20	1.21	1.09	0.86	0.77
21 – 30	1.27	1.20	0.86	0.77
31 – 40	1.30	1.10	0.85	0.75
41 – 50	0.99	0.96	0.70	0.66
51 – 60	1.24	1.29	0.89	0.71
61 – 70	1.24	1.26	0.96	0.91
71 – 80	1.40	1.10	0.88	1.33
81 – 90	1.28	1.17	0.89	1.68
91 – 100	1.46	1.40	0.94	1.66
101 – 110	1.15	0.99	0.74	1.06
111 – 120	1.05	1.02	0.73	0.75
121 – 130	1.16	1.07	0.70	0.77
131 – 140	1.01	1.06	0.79	0.75
141 – 150	1.74	1.17	0.83	0.79
151 – 160	1.66	1.06	0.70	0.75
161 – 170	**3.02**	1.15	0.85	0.76
171 – 180	**4.04**	1.19	0.77	0.82
181 – 190	**2.14**	1.74	1.09	0.82
191 – 200	1.43	1.30	0.84	0.80
201 – 210	1.35	1.38	**2.07**	0.94
211 – 220	1.44	1.42	**3.92**	0.82
221 – 230	1.40	1.55	**2.70**	0.87
231 – 240	1.33	1.21	1.40	0.84
241 – 250	1.51	1.47	1.13	0.59
251 – 260	1.26	1.30	0.89	0.80
261 – 270	1.33	1.60	0.74	0.89
271 – 280	1.47	**2.37**	0.83	0.89
281 – 290	1.29	**3.67**	0.75	0.89
291 – 300	1.23	**2.52**	0.80	0.83
301 – 310	1.15	1.90	0.77	0.79
311 – 320	1.32	1.36	0.83	0.92
321 – 330	1.11	1.03	0.70	0.82
331 – 340	1.10	1.07	0.70	0.83
341 – 350	1.08	1.00	0.68	0.86
351 – 360	1.09	0.93	0.67	0.89

For the key wind directions the average ratios are higher than two. This would indicate that in the directions where the wind is blowing from the stacks to the monitors, the disagreement between model and the monitor is greatest.

Table 17

Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.00	1.00	0.51	1.00
11 – 20	1.00	1.00	0.67	0.75
21 – 30	1.00	1.00	0.60	0.67
31 – 40	1.00	1.00	0.52	0.65
41 – 50	1.00	1.00	0.54	0.57
51 – 60	1.00	1.00	0.62	0.63
61 – 70	1.00	1.00	0.67	0.67
71 – 80	1.00	1.00	0.71	0.60
81 – 90	1.00	1.00	0.67	0.69
91 – 100	1.00	1.00	0.67	0.75
101 – 110	1.00	0.93	0.60	0.67
111 – 120	1.00	1.00	0.51	0.67
121 – 130	1.00	1.00	0.51	0.67
131 – 140	1.00	1.00	0.67	0.62
141 – 150	1.00	1.00	0.66	0.67
151 – 160	1.00	1.00	0.50	0.65
161 – 170	1.00	1.00	0.67	0.67
171 – 180	1.00	1.00	0.58	1.00
181 – 190	1.00	1.00	0.50	0.75
191 – 200	1.00	1.00	0.50	0.67
201 – 210	1.00	1.00	0.59	0.77
211 – 220	1.00	1.00	0.98	0.67
221 – 230	1.00	1.00	0.78	0.67
231 – 240	1.00	1.00	0.50	0.55
241 – 250	1.00	1.00	0.58	0.86
251 – 260	1.00	1.00	0.60	0.80
261 – 270	1.00	1.00	0.50	0.67
271 – 280	1.00	1.00	0.50	0.71
281 – 290	1.00	1.00	0.50	0.78
291 – 300	1.00	1.00	0.59	0.67
301 – 310	1.00	0.67	0.67	0.75
311 – 320	1.00	0.50	0.58	0.67
321 – 330	1.00	0.67	0.51	1.00
331 – 340	1.00	0.67	0.52	1.00
341 – 350	1.00	1.00	0.50	1.00
351 – 360	1.00	1.00	0.50	1.00

Table 17 shows the median ratios of modeled to monitored concentrations versus wind direction. Very few high ratios are ween for any wind directions

Comparisons Not in Time

U.S. EPA does not believe that these values should be paired in time. While we do not agree we wish to show the results of such an analysis. In this case the modeled and monitored values are ranked from lowest to highest and then paired. Figures 30 through 33 show the results. For the Mt. Carmel Site (Figure 30) AERMOD over-predicts in a range of 20 to 50 ppb. The East Site (Figure 31) shows AERMOD predicts within a factor of two for the entire range. The Coal Road Site (Figure 32) shows AERMOD predicts within a factor of two except for all concentrations. The Schrodt Site (Figure 33) shows AERMOD predicts within a factor of two for all concentrations.

IDEM believes that it is not appropriate to compare the data in this fashion. Since each hour has a different emission rate, comparison of different hours is comparing apples and oranges. Without making corrections for emission rates, an accurate assessment of a comparison of this type is not appropriate.

However, it is possible to compare the data without actually comparing individual hours at all. Table 18 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the number of hours that exceed the standard of 35 parts per billion (ppb). For the Mt. Carmel site AERMOD predicts 12 hours above the standard, while the monitor only measured 6. For the East site AERMOD predicts 8 hours above the standard, while the monitor measured none. For the Coal Road site AERMOD predicts 18 hours above the standard, while the monitor measured 4. For the Schrodt site AERMOD predicts 9 hours above the standard, while the monitor measured none.

Figure 30

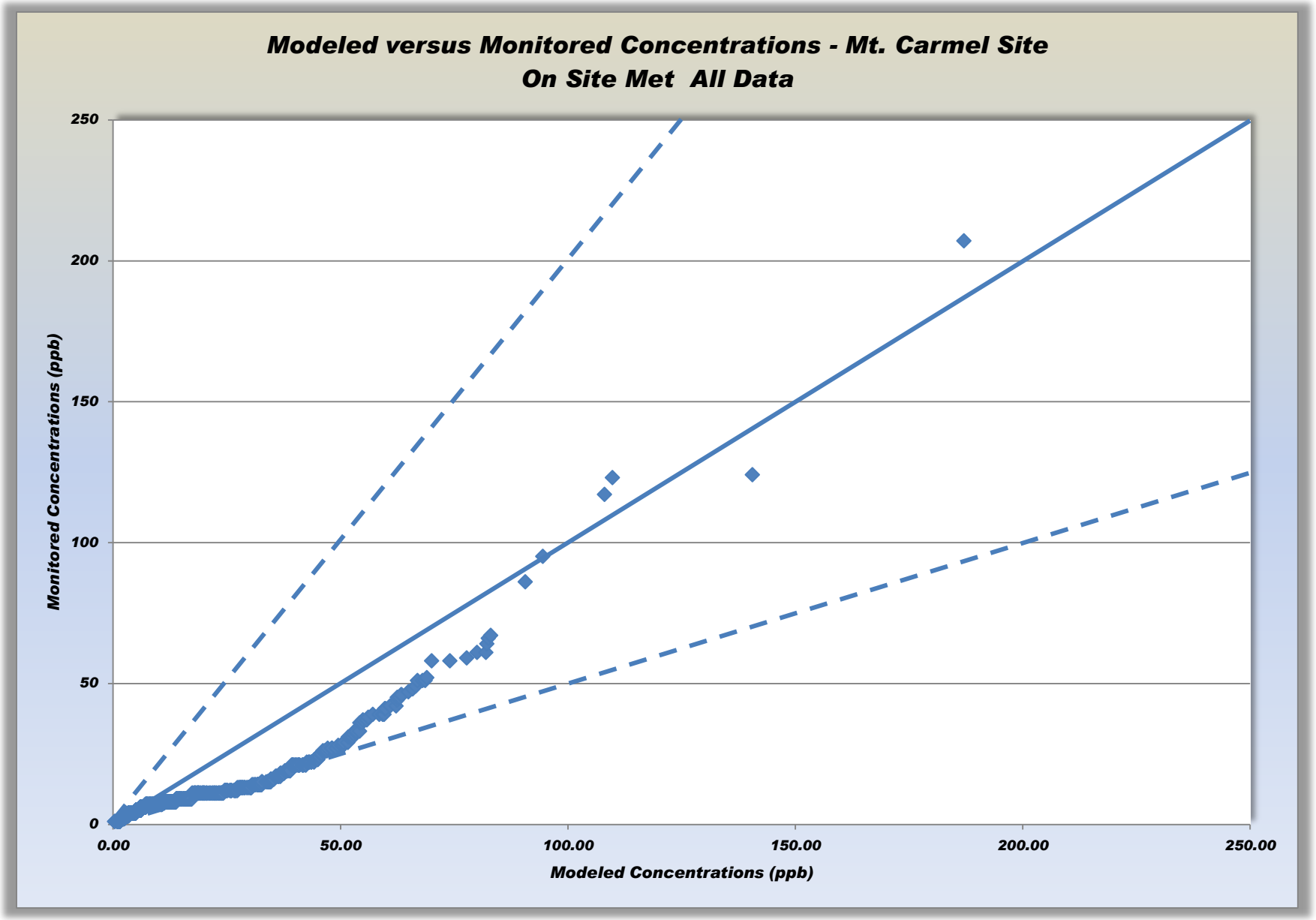

Modeled versus Monitored Concentrations - Mt. Carmel Site
On Site Met All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
50
100
150
200
250
0.00
50.00
100.00
150.00
200.00
250.00

Figure 31

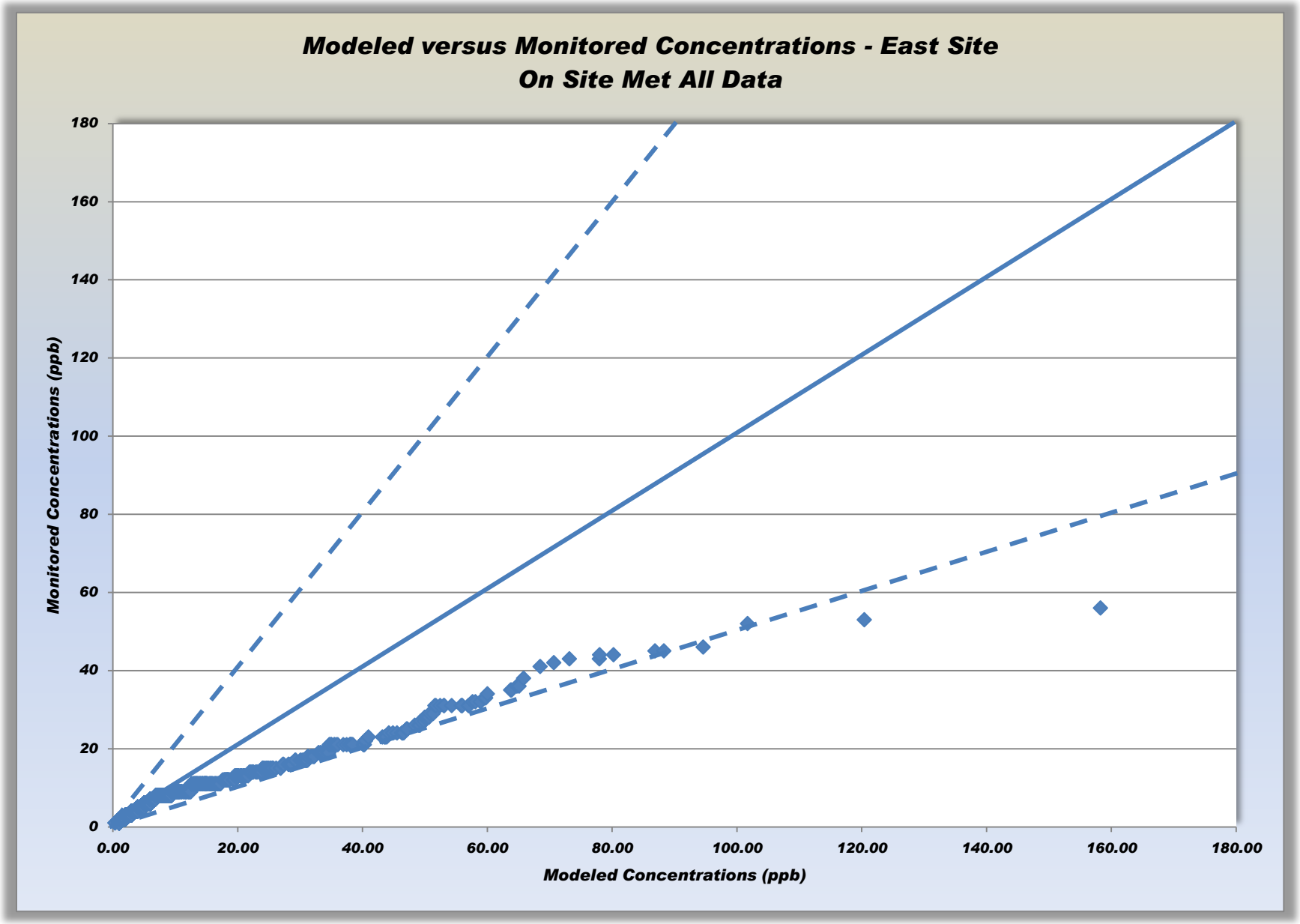

Modeled versus Monitored Concentrations - East Site
On Site Met All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00

Figure 32

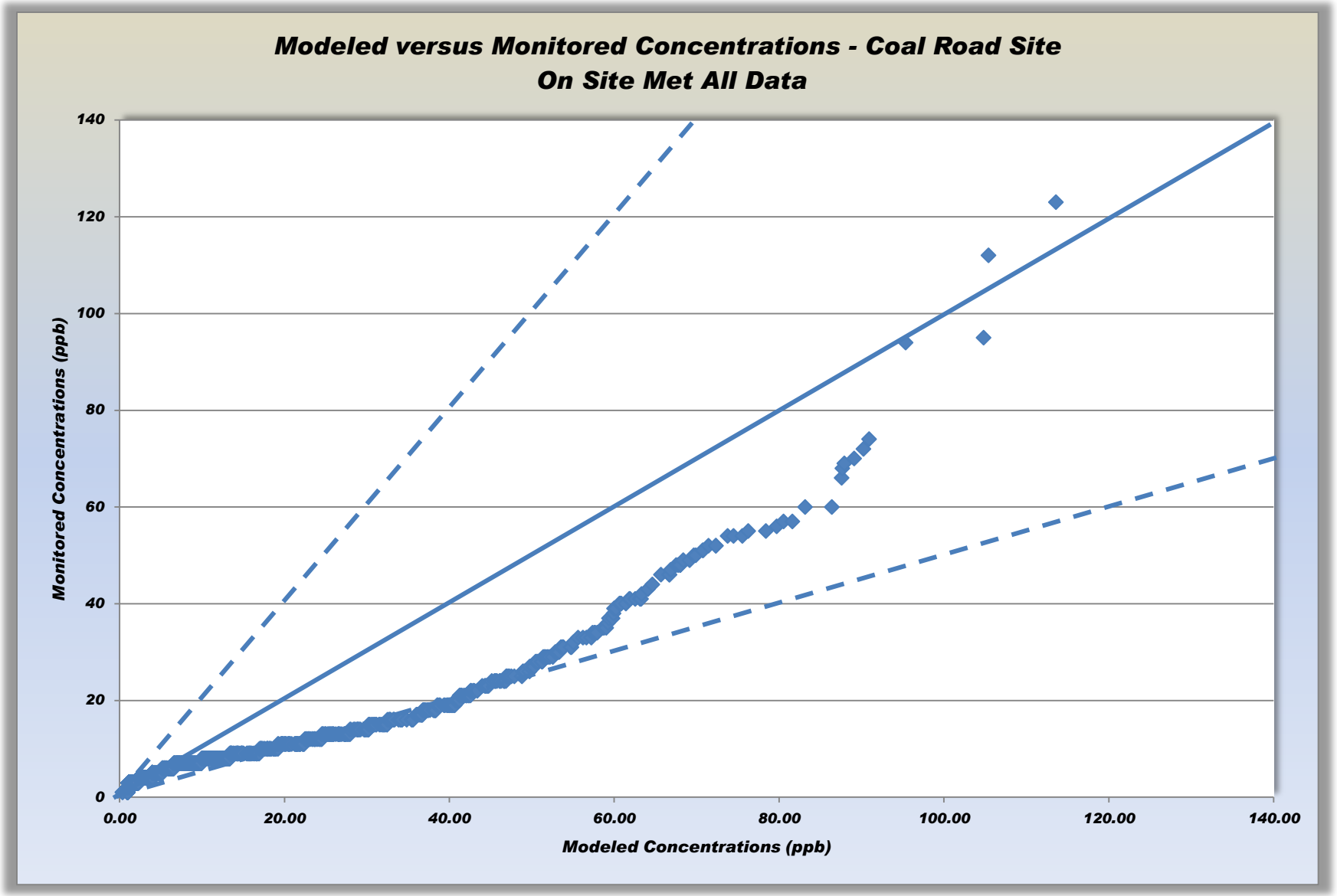

Modeled versus Monitored Concentrations - Coal Road Site
On Site Met All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Figure 33

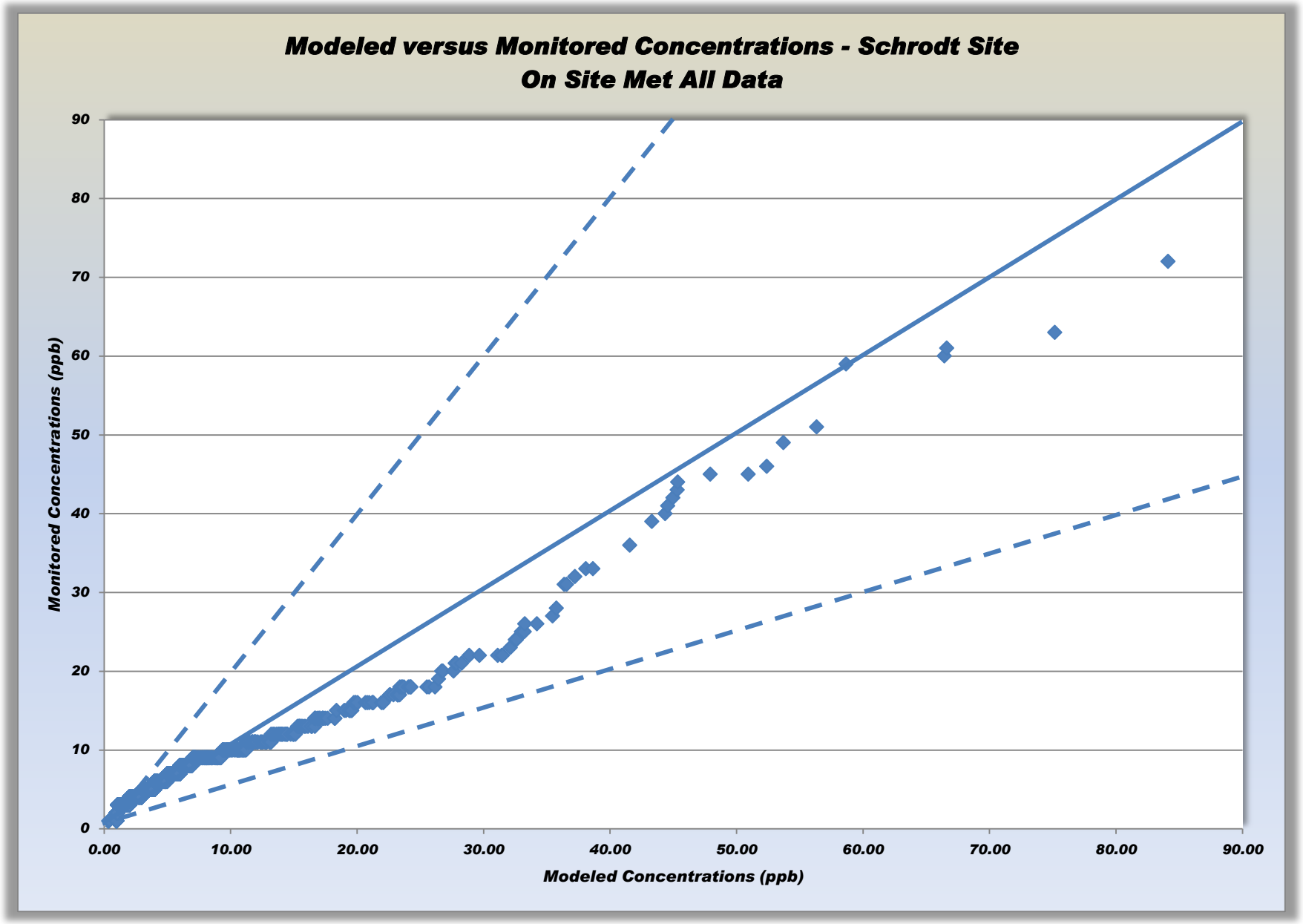

Modeled versus Monitored Concentrations - Schrodt Site
On Site Met All Data
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

Table 18
Hours within Selected Ranges – Scenario 3 – All Data

	Mt. Carmel		East		Coal Road		Schrodt	
Range	**Model**	**Monitor**	**Model**	**Monitor**	**Model**	**Monitor**	**Model**	**Monitor**
1 – 25	8001	8147	8226	8314	8057	8247	8272	8293
26 – 50	157	48	95	43	196	77	38	20
51 – 75	43	12	30	3	78	21	7	6
76 – 100	8	2	5	0	15	2	2	0
101 – 125	2	3	2	0	3	2	0	0
126 – 150	1	0	0	0	0	0	0	0
151 – 175	0	0	1	0	0	0	0	0
176 – 200	1	0	0	0	0	0	0	0
201 – 225	0	1	0	0	0	0	0	0
Total	8213	8213	8360	8360	8349	8349	8319	8319
Above 75	12	6	8	0	18	4	9	0

Non-Zero Predictions Only

The analyses presented so far have used all data where both the predicted and the monitored values are available for an hour. However, the majority of these readings are non-meaningful. In most cases AERMOD predicts a zero value which then has a background value added and then is compared to the monitored value. This is not a true measure of how the model is working. Model predictions of zero are of little interest except for computing an annual average value. This set of analyses removes all hours where the AERMOD predicted value was zero.

Mt. Carmel Site

Figure 34 shows a comparison of predicted and measured SO2 levels compared in time for the Mt. Carmel site. Of the 3,173 hours of data, 73.7 percent are predicted within a factor of two, while 6.8 percent are under-predicted by more than a factor of two and 19.5 percent are over-predicted by more than a factor of two.

East Site

Figure 35 shows a comparison of predicted and measured SO2 levels compared in time for the East site. Of the 2,843 hours of data, 73.0 percent are predicted within a factor of two, while 8.3 percent are under-predicted by more than a factor of two and 18.7 percent are over-predicted by more than a factor of two.

Coal Road Site

Figure 36 shows a comparison of predicted and measured SO2 levels compared in time for the Coal Road site. Of the 3,236 hours of data, 65.0 percent are predicted within a factor of two, while 16.1 percent are under-predicted by more than a factor of two and 18.9 percent are over-predicted by more than a factor of two.

Schrodt Site

Figure 37 shows a comparison of predicted and measured SO2 levels compared in time for the Schrodt site. Of the 3,412 hours of data, 76.6 percent are predicted within a factor of two, while 15.8 percent are under-predicted by more than a factor of two and 7.6 percent are over-predicted by more than a factor of two.

SUMMARY

Table 19 summarizes the results for all four sites. Overall 72.1 percent of the predictions are within a factor of two of the measured values, 11.9 percent are under-predicted by more than a factor of two and 16.0 percent are over-predicted by more than a factor of two. The performance of AERMOD is not as good as shown earlier. Fewer predictions are within the factor of two.

Table 19
Results of Scenario 3 Analyses – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**	**No.**	**Percent**
<0.5	216	6.8	235	8.3	522	16.1	539	15.8	1512	11.9
0.5 – 2.0	2340	73.7	2074	73.0	2102	65.0	2612	76.6	9128	72.1
➢ **2.0**	617	19.5	534	18.7	612	18.9	261	7.6	2024	16.0
Total	3173		2843		3236		3412		12664	

Figure 34

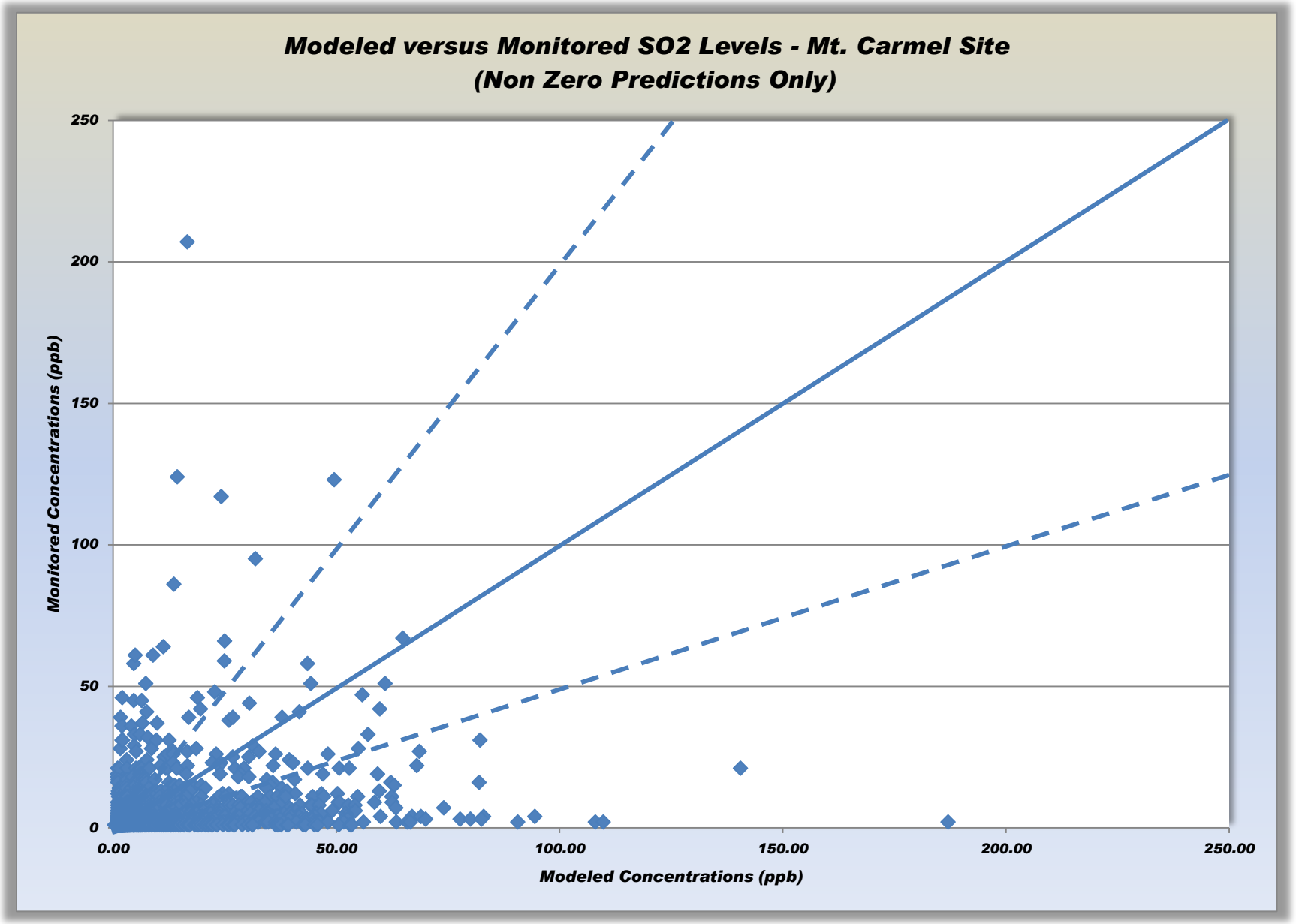

Modeled versus Monitored SO2 Levels - Mt. Carmel Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
250
200
150
100
50
0
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

Figure 35

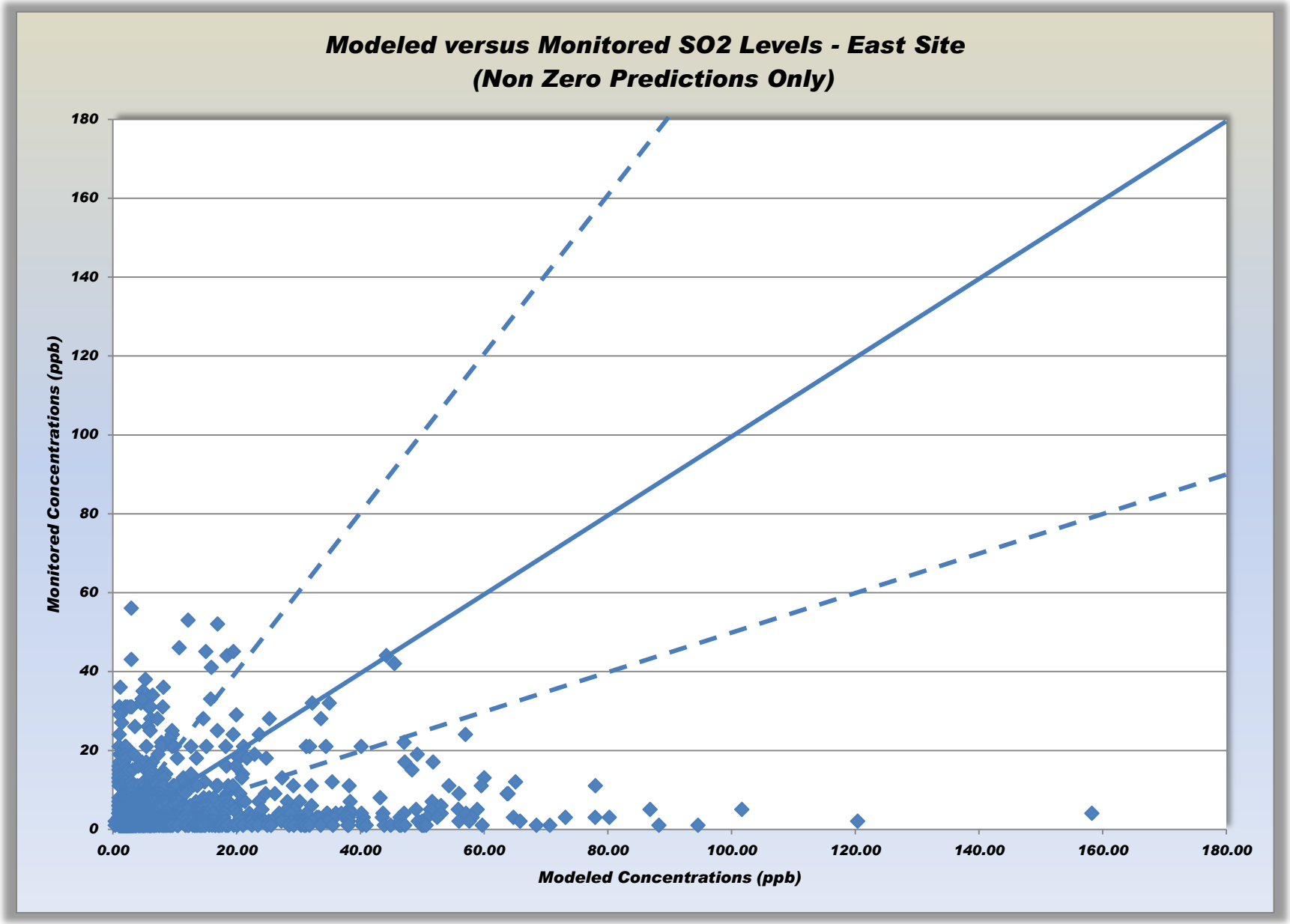

Modeled versus Monitored SO2 Levels - East Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Modeled Concentrations (ppb)

Figure 36

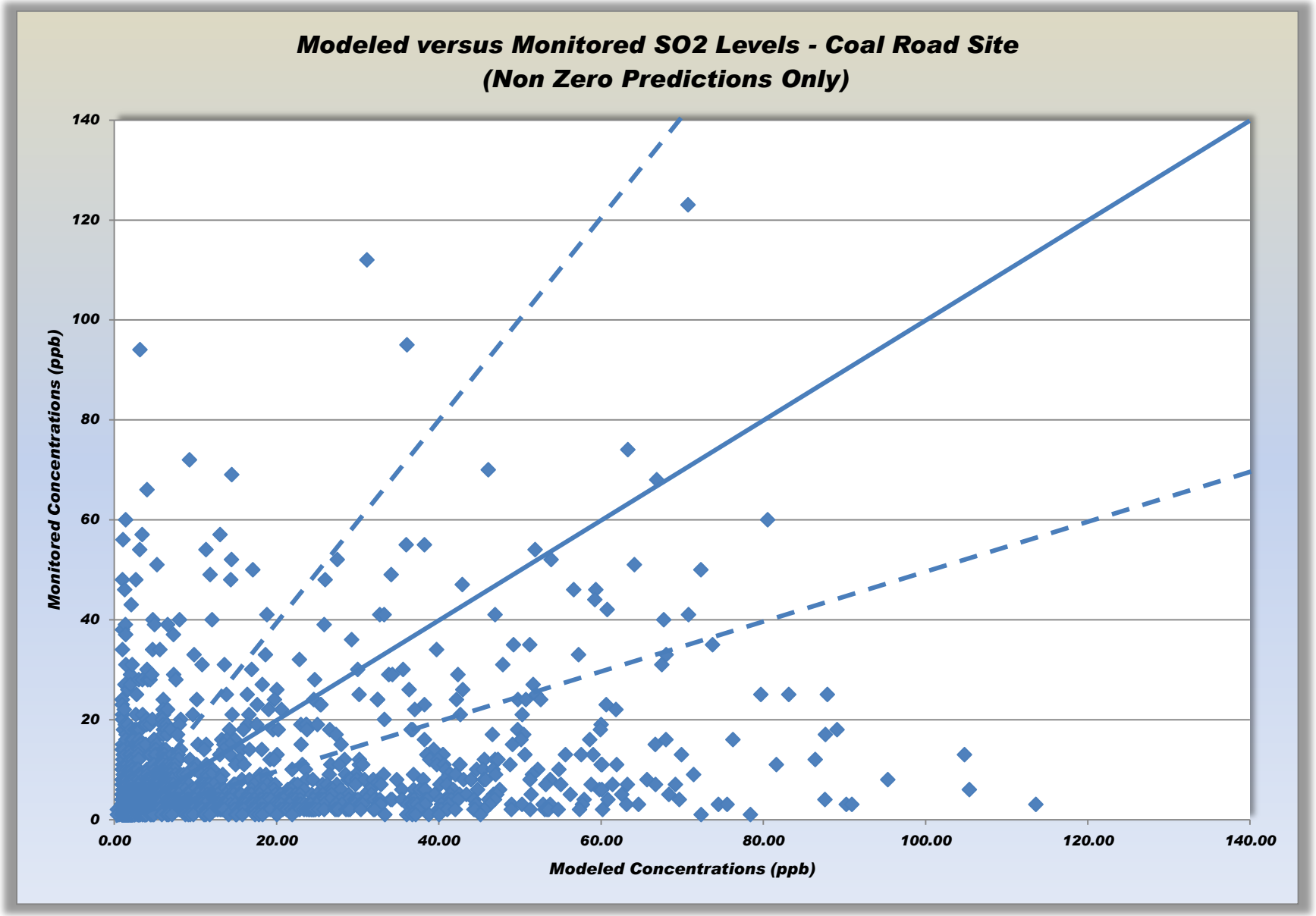
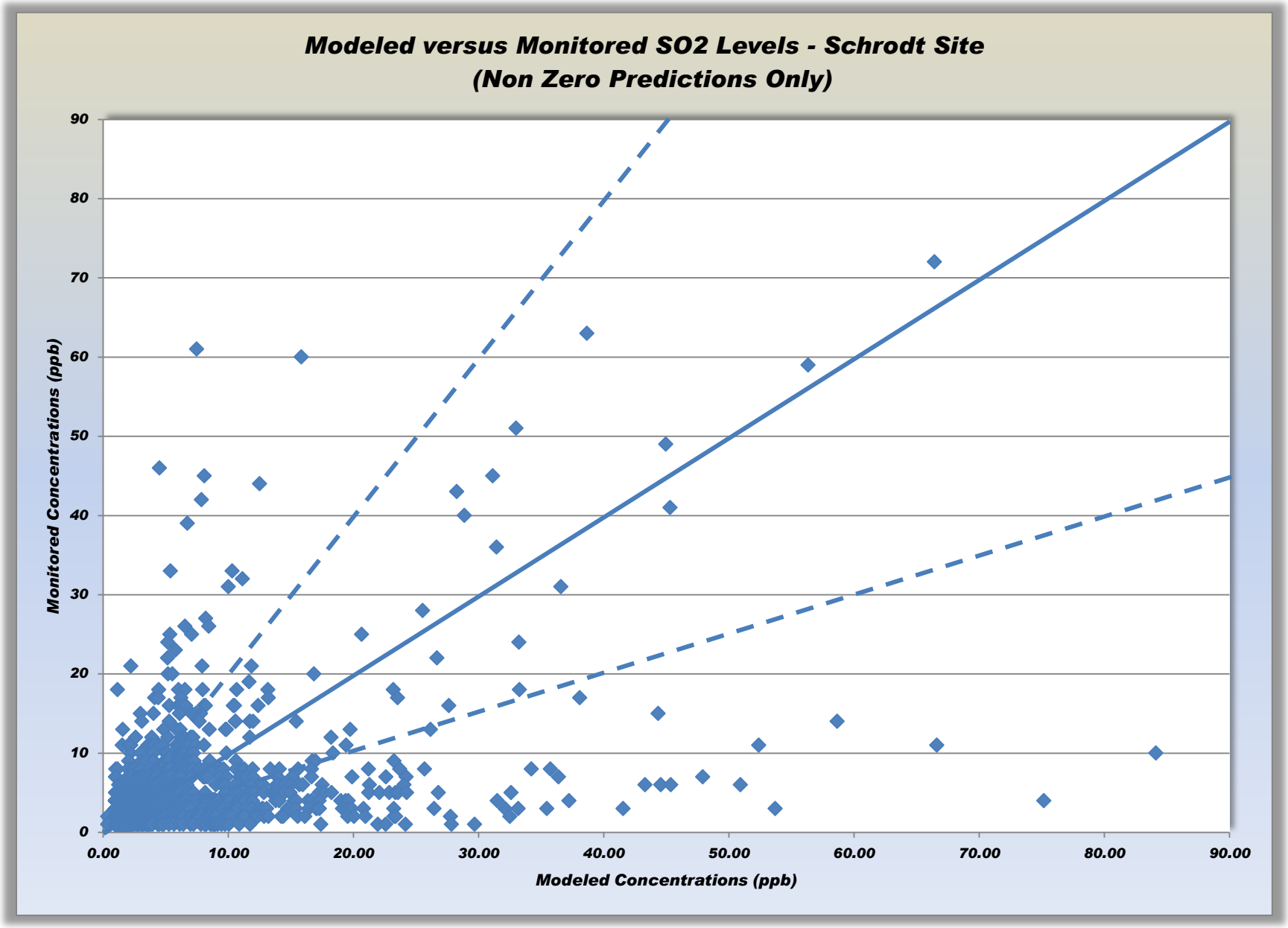

Modeled versus Monitored SO2 Levels - Coal Road Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Figure 37


Modeled versus Monitored SO2 Levels - Schrodt Site
(Non Zero Predictions Only)
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

Wind Speed Analysis

Table 20 shows the average ratio of modeled divided by monitored concentrations versus wind speed. In general each of the sites shows that the ratios drop off with wind speed. In some cases the higher wind speeds have higher ratios, but this is likely due to smaller sample size.

Table 20

Comparison of Average Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	9.38	11.69	6.24	4.37
1.01 – 2	3.91	4.60	2.81	1.99
2.01 – 3	2.66	2.78	2.13	1.09
3.01 – 4	2.09	1.93	1.62	0.85
4.01 – 5	2.06	1.25	1.33	0.78
5.01 – 6	1.43	1.15	1.53	0.76
6.01 – 7	1.52	1.06	1.29	0.81
7.01 – 8	1.58	1.10	1.74	0.83
8.01 – 9	1.04	0.96	1.27	0.89
9.01 – 10	1.22	0.87	1.79	0.81
➢ 10	1.41	0.94	1.66	0.85

Some persons would argue that using average values is inappropriate. Because the sample size of some categories may be small, one high ratio can overly impact the average. Table 21 shows the median ratios versus wind speed. The trends seen in the average data appear to be duplicated in the median data.

Table 21

Comparison of Median Modeled/Monitored Ratios versus Wind Speed

Wind Speed Range	Mt. Carmel	East	Coal Road	Schrodt
0 -1 m/s	4.67	7.50	3.88	3.16
1.01 – 2	2.23	2.12	1.54	1.40
2.01 – 3	1.45	1.33	1.01	0.83
3.01 – 4	1.12	1.07	0.78	0.69
4.01 – 5	1.03	1.01	0.67	0.68
5.01 – 6	1.05	1.02	0.58	0.75
6.01 – 7	1.04	1.01	0.54	1.00
7.01 – 8	1.02	1.00	0.66	1.00
8.01 – 9	1.02	1.01	0.54	1.01
9.01 – 10	1.03	1.02	0.53	1.01
➢ 10	1.01	1.01	0.52	1.01

Wind Direction Analysis

Table 22 compares average modeled to monitored ratios versus wind direction. The directions which are directly from the stacks to the monitors are highlighted in the table.

Table 22

Comparison of Average Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.45	1.25	1.01	0.92
11 – 20	1.61	1.57	1.19	0.87
21 – 30	1.91	1.97	1.23	0.94
31 – 40	**2.04**	1.77	1.29	0.99
41 – 50	1.23	1.36	0.85	0.80
51 – 60	1.88	**2.46**	1.39	0.93
61 – 70	1.84	**2.15**	1.54	1.36
71 – 80	**2.25**	1.86	1.26	**2.51**
81 – 90	**2.12**	**2.32**	1.50	**2.60**
91 – 100	**2.84**	**3.40**	1.75	**2.99**
101 – 110	1.76	1.62	0.96	**2.08**
111 – 120	1.33	1.45	0.96	0.93
121 – 130	1.60	1.51	0.88	0.97
131 – 140	1.23	1.58	1.06	0.98
141 – 150	**3.66**	**2.04**	1.32	1.00
151 – 160	**4.09**	**2.45**	1.15	1.04
161 – 170	**4.10**	**2.18**	1.34	0.93
171 – 180	**5.52**	**2.02**	1.05	1.01
181 – 190	**3.93**	**4.05**	**2.19**	1.09
191 – 200	**2.35**	**2.32**	1.41	1.07
201 – 210	1.94	**2.36**	**3.30**	1.27
211 – 220	**2.04**	**2.27**	**4.94**	1.01
221 – 230	1.82	**2.35**	**3.57**	1.04
231 – 240	1.61	1.53	**2.11**	1.00
241 – 250	**2.00**	**2.15**	1.66	1.06
251 – 260	1.66	**2.07**	1.30	0.95
261 – 270	1.94	**3.39**	1.03	1.19
271 – 280	**2.24**	**5.81**	1.26	1.06
281 – 290	1.67	**7.44**	1.04	1.07
291 – 300	1.64	**4.24**	1.18	0.99
301 – 310	1.54	**3.59**	1.08	0.85
311 – 320	1.88	**2.69**	1.19	1.22
321 – 330	1.46	**2.01**	0.95	0.95
331 – 340	1.45	1.90	0.93	0.98
341 – 350	1.34	1.39	0.87	0.93
351 – 360	1.41	1.21	0.94	1.08

For the key wind directions the average ratios are much higher than two. This indicates that when the wind is blowing from the stacks to the monitors the disagreement between the model and the monitor is greater.

Table 23
Comparison of Median Modeled to Monitored Ratios versus Wind Direction

WD Range	Mt. Carmel	East	Coal Road	Schrodt
0 – 10	1.15	1.05	0.75	0.89
11 – 20	1.04	1.05	0.76	0.83
21 – 30	1.03	1.01	0.72	0.77
31 – 40	1.05	1.03	0.63	1.01
41 – 50	1.05	1.00	0.58	0.65
51 – 60	1.01	1.00	0.79	0.71
61 – 70	1.07	1.19	0.90	0.93
71 – 80	1.09	1.04	0.84	1.18
81 – 90	1.02	1.04	0.86	1.34
91 – 100	1.03	1.02	1.00	1.19
101 – 110	1.03	0.74	0.71	0.84
111 – 120	1.01	1.00	0.67	0.67
121 – 130	1.02	1.00	0.69	0.87
131 – 140	1.00	1.00	0.76	0.78
141 – 150	1.04	1.03	0.70	0.80
151 – 160	1.16	1.11	0.79	0.77
161 – 170	1.23	1.05	0.90	0.67
171 – 180	**2.00**	1.05	0.74	1.01
181 – 190	1.13	1.02	0.60	1.01
191 – 200	1.02	1.08	0.68	0.90
201 – 210	1.02	1.02	1.03	1.00
211 – 220	1.06	1.05	**2.05**	0.83
221 – 230	1.16	1.11	1.27	0.88
231 – 240	1.10	1.12	0.71	0.75
241 – 250	1.16	1.10	0.81	1.01
251 – 260	1.18	1.10	0.69	1.01
261 – 270	1.09	1.16	0.62	1.01
271 – 280	1.06	1.90	0.68	0.75
281 – 290	1.10	**2.09**	0.67	1.01
291 – 300	1.09	1.13	0.64	1.01
301 – 310	1.06	0.89	0.77	0.81
311 – 320	1.04	0.50	0.67	0.76
321 – 330	1.04	0.52	0.63	1.00
331 – 340	1.03	0.75	0.67	1.00
341 – 350	1.07	1.01	0.56	1.01
351 – 360	1.07	1.10	0.70	1.02

Table 23 shows the median ratios of modeled to monitored concentrations versus wind direction. Once again the key wind directions show the largest discrepancies between the modeled and monitored concentrations. One question that will be addressed later is why are there predicted non-zero concentrations in directions where the winds are not blowing from the stack to the monitors?

A good example of this occurs on July 26, hour 11. The wind direction for this hour is 25 which do not blow toward any of the four monitors. However, as shown below, AERMOD predicts exceedances at three of the four monitors:

Monitoring Site	Predicted Concentration (ppb)
Mt. Carmel	90.63
East	120.44
Coal Road	90.25
Schrodt	44.35

It is impossible for AERMOD to accurately be predicting concentrations at each of these three monitors given the wind direction of 25. The wind speed for this hour is 0.31 meters per second.

Table 24 shows cases where the model is predicting concentrations greater than 25 parts per billion (ppb) that does not appear to be accurate given the wind direction. In each case the wind speed is less than one meter per second. It would appear that AERMOD has some flaw that leads to erroneous predictions under low wind speeds.

Table 24

Outlier Predictions (> 25 ppb)

Site	Month	Day	Hour	WS	WD	Model	Monitor
Mt. Carmel	7	26	11	0.31	25	90.63	2
Mt. Carmel	7	26	10	0.36	67	70.05	3
Mt. Carmel	4	19	10	0.31	315	68.96	4
Mt. Carmel	4	12	9	0.36	90	63.47	2
Mt. Carmel	3	8	13	0.41	240	62.45	11
Mt. Carmel	5	19	16	0.31	92	53.47	1
Mt. Carmel	9	12	10	0.31	319	45.01	2
Mt. Carmel	3	8	15	0.41	244	47.01	19
Mt. Carmel	11	3	14	0.31	260	46.14	8
Mt. Carmel	4	19	9	0.46	17	41.78	5
Mt. Carmel	8	9	11	0.82	232	39.84	4
East	7	26	11	0.31	25	120.44	2
East	8	13	10	0.41	197	78.29	1
East	7	26	10	0.36	67	80.26	3
East	6	21	12	0.51	187	70.67	1
East	5	19	16	0.31	92	68.47	1
East	4	13	13	0.31	196	64.77	3
East	7	12	13	0.67	153	63.75	9
East	8	15	10	0.41	186	59.74	1
East	8	9	13	0.36	228	57.08	4
East	4	12	9	0.36	90	55.98	2
East	3	8	15	0.41	244	55.98	9
East	8	10	11	0.62	188	50.65	1
East	8	12	13	0.41	190	49.95	1
East	8	9	11	0.82	242	49.99	2
East	4	11	11	0.51	207	49.37	2
East	7	16	16	0.36	125	51.36	5
East	5	26	11	0.62	233	47.19	7
East	8	2	13	0.51	214	49.03	5
East	7	26	16	0.41	57	40.31	1
East	9	9	14	0.51	160	40.50	3
East	7	14	10	0.36	176	40.40	2
Coal Road	7	26	11	0.31	25	90.25	3
Coal Road	7	26	10	0.36	67	69.65	4
Coal Road	4	19	10	0.31	315	68.38	5
Coal Road	4	12	9	0.36	90	63.16	3
Coal Road	5	19	16	0.31	92	53.35	2
Coal Road	7	12	13	0.67	153	50.15	16
Coal Road	9	12	10	0.31	319	44.59	3
Coal Road	4	19	9	0.46	17	41.42	5
Schrodt	7	26	11	0.31	25	44.35	15

The only outliers that were investigated in this analysis were those that exceeded 25 ppb. There may be many other hours where this same behavior is occurring.

Comparisons Not in Time

Figures 38 – 41 show predicted concentrations versus monitored concentrations where the values have independently been ranked from lowest to highest. Figure 38 (Mt. Carmel) shows nearly all predictions are within a factor of two. Figure 39 (East) shows nearly all predictions are within a factor of two. Figure 40 (Coal Road) shows nearly all predictions are within a factor of two. Figure 41 (Schrodt) shows nearly all predictions are within a factor of two.

Figure 38

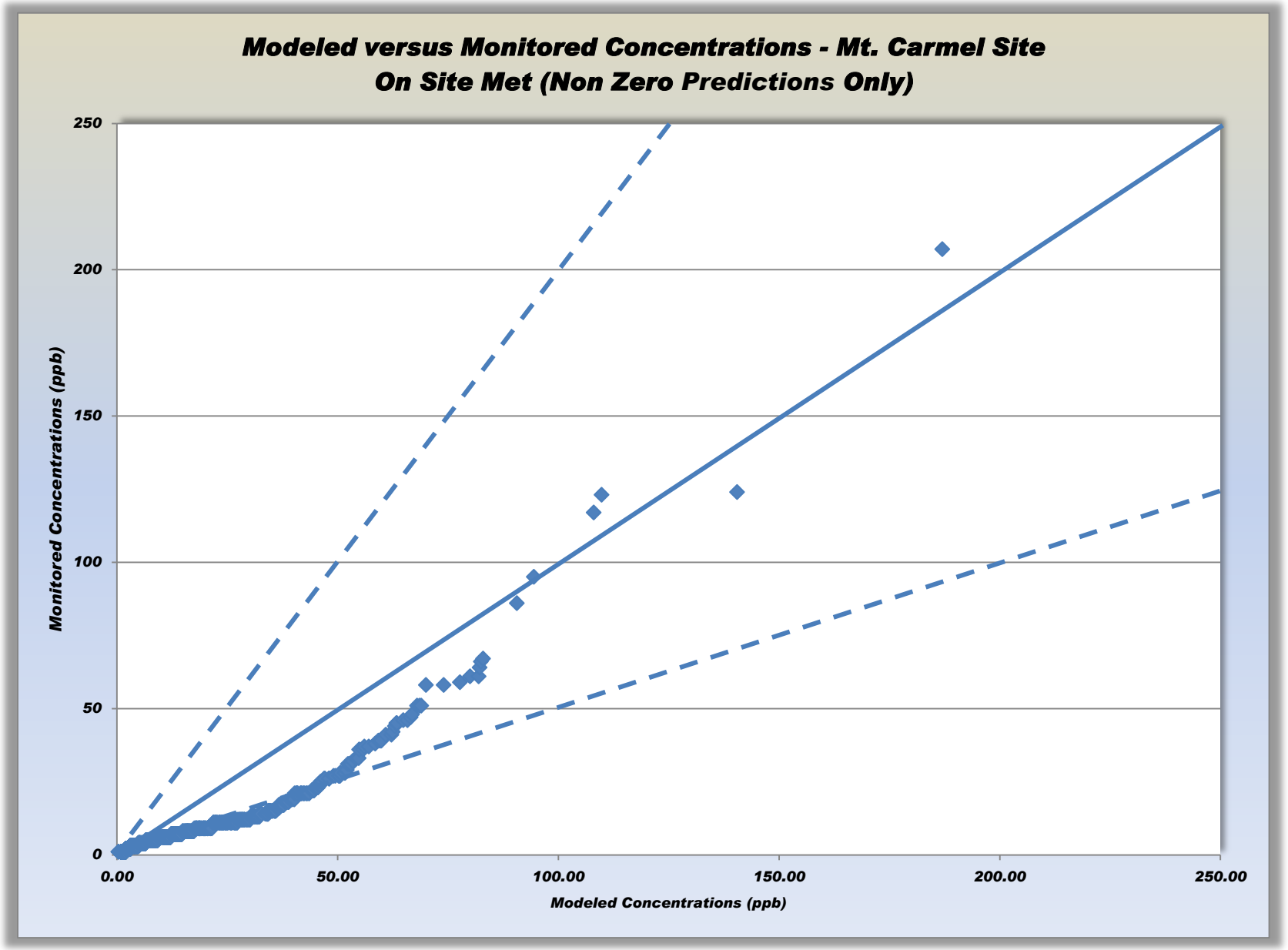

Modeled versus Monitored Concentrations - Mt. Carmel Site
On Site Met (Non Zero Predictions Only)
Monitored Concentrations (ppb)
250
200
150
100
50
0
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

Figure 39

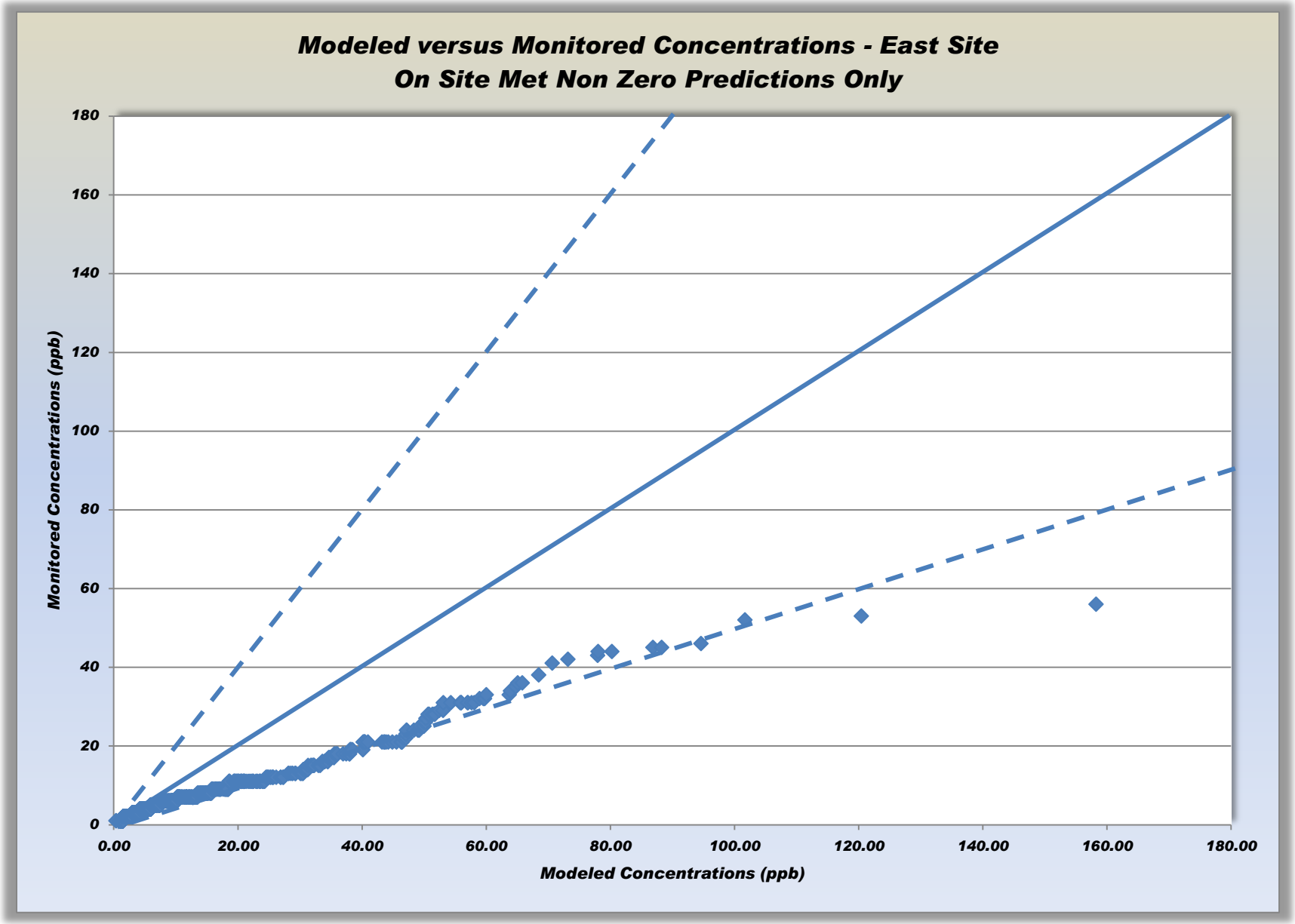

Modeled versus Monitored Concentrations - East Site
On Site Met Non Zero Predictions Only
Monitored Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Modeled Concentrations (ppb)

Figure 40

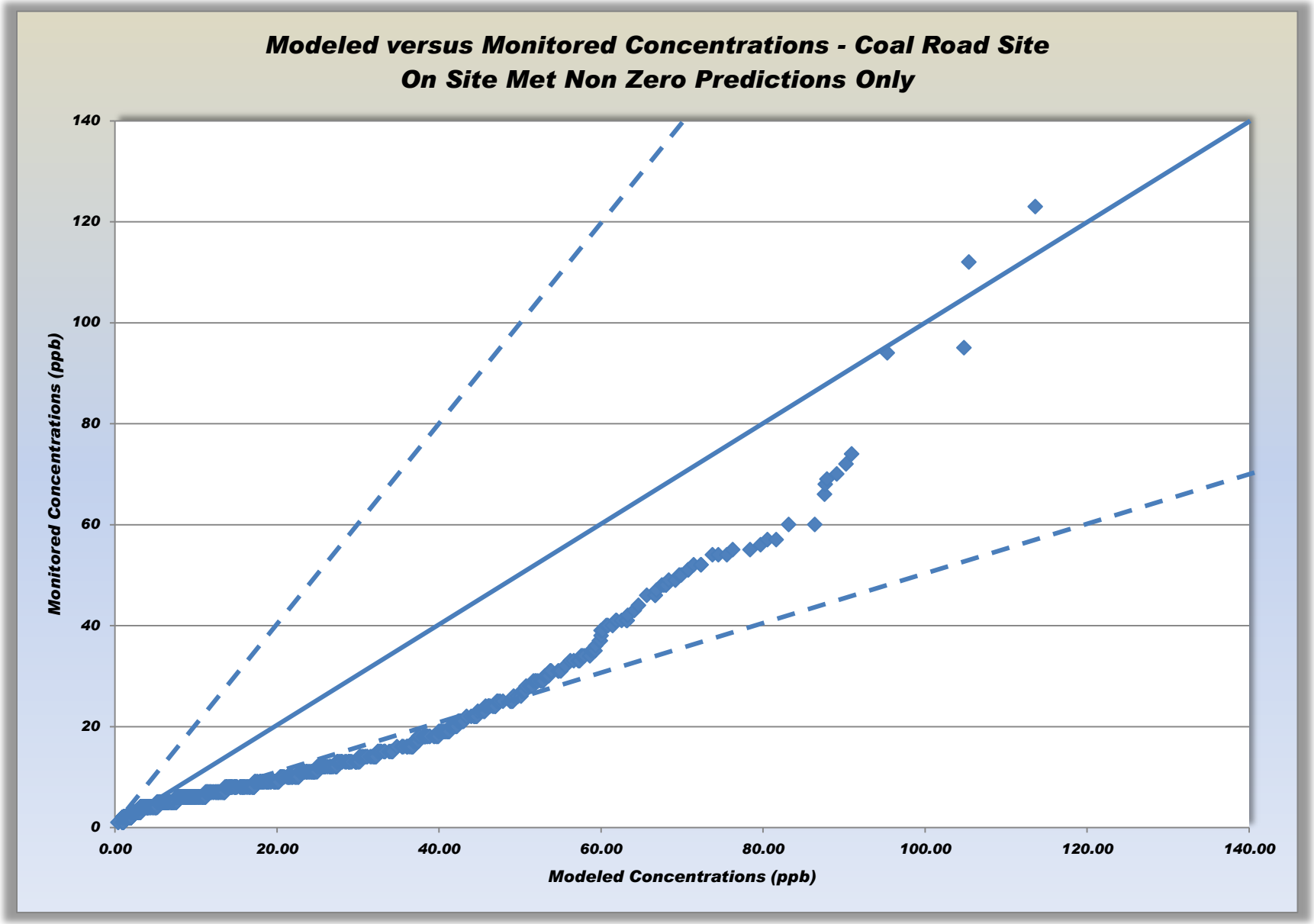
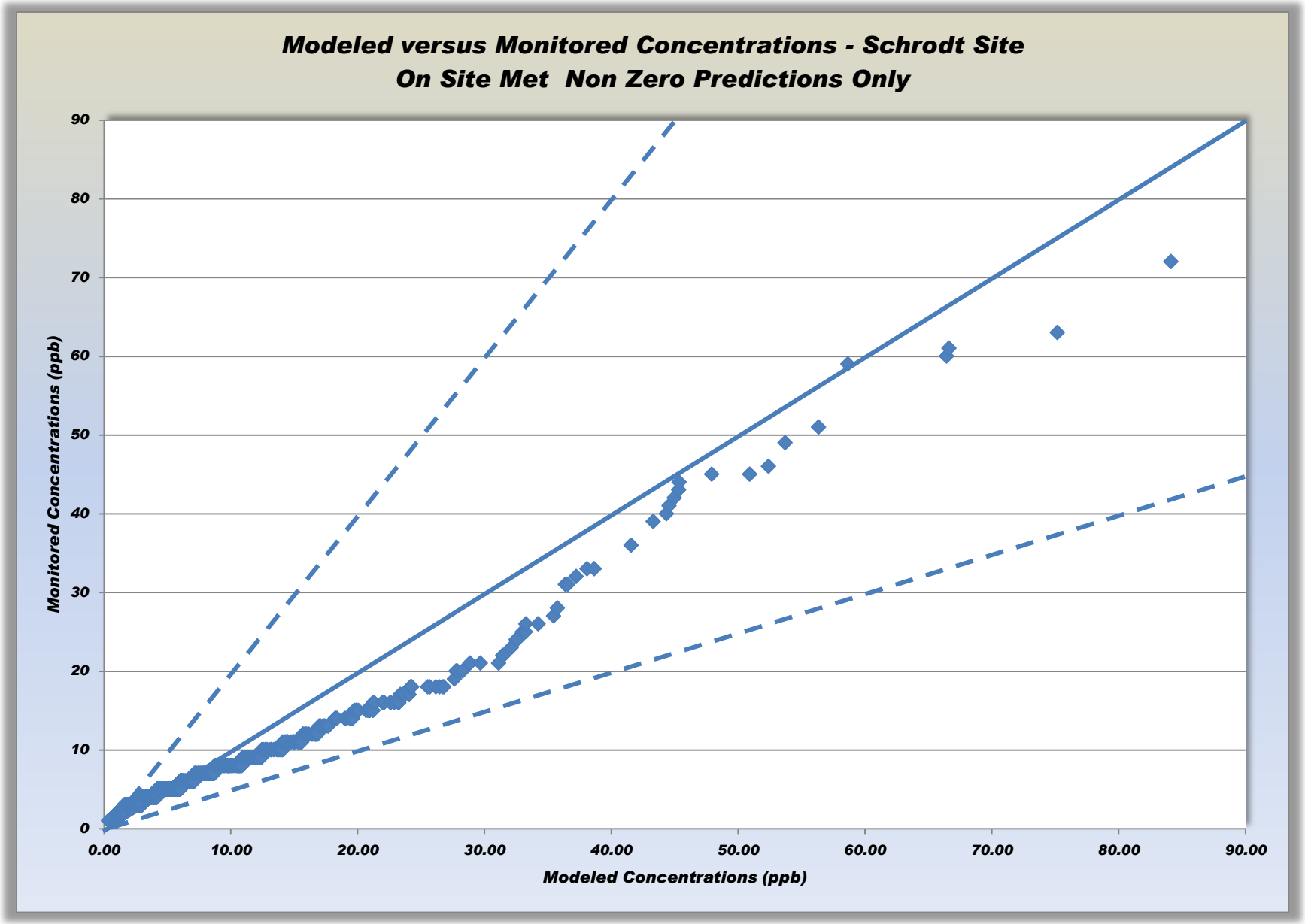

Modeled versus Monitored Concentrations - Coal Road Site
On Site Met Non Zero Predictions Only
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Figure 41


Modeled versus Monitored Concentrations - Schrodt Site
On Site Met Non Zero Predictions Only
Monitored Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Modeled Concentrations (ppb)

When compared in this fashion, the following overall statistics (ratios of modeled to monitored concentrations) are found:

Ratio	Mt. Carmel		East		Coal Road		Schrodt		Total	
Range	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
< 0.5	2	0.1	2	0.1	2	0.1	2	0.1	8	0.1
0.5 – 2	2930	92.3	2726	95.8	2945	91.0	3410	99.9	12011	94.8
➢ 2.0	241	7.6	115	4.1	289	8.9	0	0.0	645	5.1
Total	3173		2843		3236		3412		12664	

This appears to show significant over-prediction with no under-prediction.

Table 25 looks at the frequency at which modeled and monitored concentrations occur within certain concentration ranges. Of particular interest are the numbers of hours that exceed the standard of 35 ppb. Overall AERMOD predicts 41 hours above the standard while the monitors measured 10.

Table 25
Hours within Selected Ranges – Scenario 3 – Non-Zero Predictions Only

	Mt. Carmel		East		Coal Road		Schrodt	
Range	Model	Monitor	Model	Monitor	Model	Monitor	Model	Monitor
1–25	2961	3111	2311	2803	2949	3137	3366	3386
26–50	157	45	95	37	195	74	37	20
51–75	43	11	28	3	74	10	7	6
76–100	8	2	6	1	14	2	2	0
101–125	2	3	2	0	3	2	0	0
126-150	1	0	0	0	0	0	0	0
151-175	0	0	1	0	0	0	0	0
176-200	1	0	5	0	0	0	0	0
201-225	0	1	0	0	0	0	0	0
Total	3173	3173	2843	2843	3236	3236	3410	3410
Above 75	12	6	9	0	18	4	2	0

Predictions Greater Than 35 ppb

Even when looking at non-zero predicted hours, the majority of the concentrations are in the range of 1 to 10 ppb. This range is of little interest in the regulatory scheme. When the model predicts concentrations at or above 35 ppb, nearly half of the level of the national ambient air quality standard for SO2, model performance is much more of an issue. This section focuses on predicted SO2 concentrations that are 35 ppb or greater.

Mt. Carmel Site

Figure 42 shows a comparison of modeled and monitored SO2 concentrations for the Mt. Carmel site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 135 hours of ratios (modeled to monitored) shown, sixteen are within a factor of two range (11.9 percent) while 118 hours are above a factor of two (87.4percent) and one is under-predicted by more than a factor of two (0.07 percent).

East Site

Figure 43 shows a comparison of modeled and monitored SO2 concentrations for the East site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 85 hours of ratios (modeled to monitored) shown, four are within a factor of two range (4.7 percent), while 81 hours are above the factor of two (95.3 percent).

Coal Road Site

Figure 44 shows a comparison of modeled and monitored SO2 concentrations for the Coal Rd. site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 204 hours of ratios (modeled to monitored) shown, 32 are within a factor of two (15.7 percent), while 171 hours are above the factor of two (83.8 percent) and one is under-predicted by more than a factor of two (0.5 percent).

Schrodt Site

Figure 45 shows a comparison of modeled and monitored SO2 concentrations for the Schrodt site for those hours where AERMOD predicts a maximum concentration of 35 ppb or greater. Of the 24 hours of ratios (modeled to monitored) shown, six are within a factor of two (25.0 percent) while 18 hours are above the factor of two (75.0 percent).

Overall this indicates that AERMOD is over-predicting 86.6 percent of the predicted concentrations that are 35 ppb or greater. In only 2 cases is it under-predicting these concentrations. In 12.9 percent of the cases are the predictions within a factor of two. This would indicate serious problems with the model, both in accuracy and over-prediction.

Figure 42

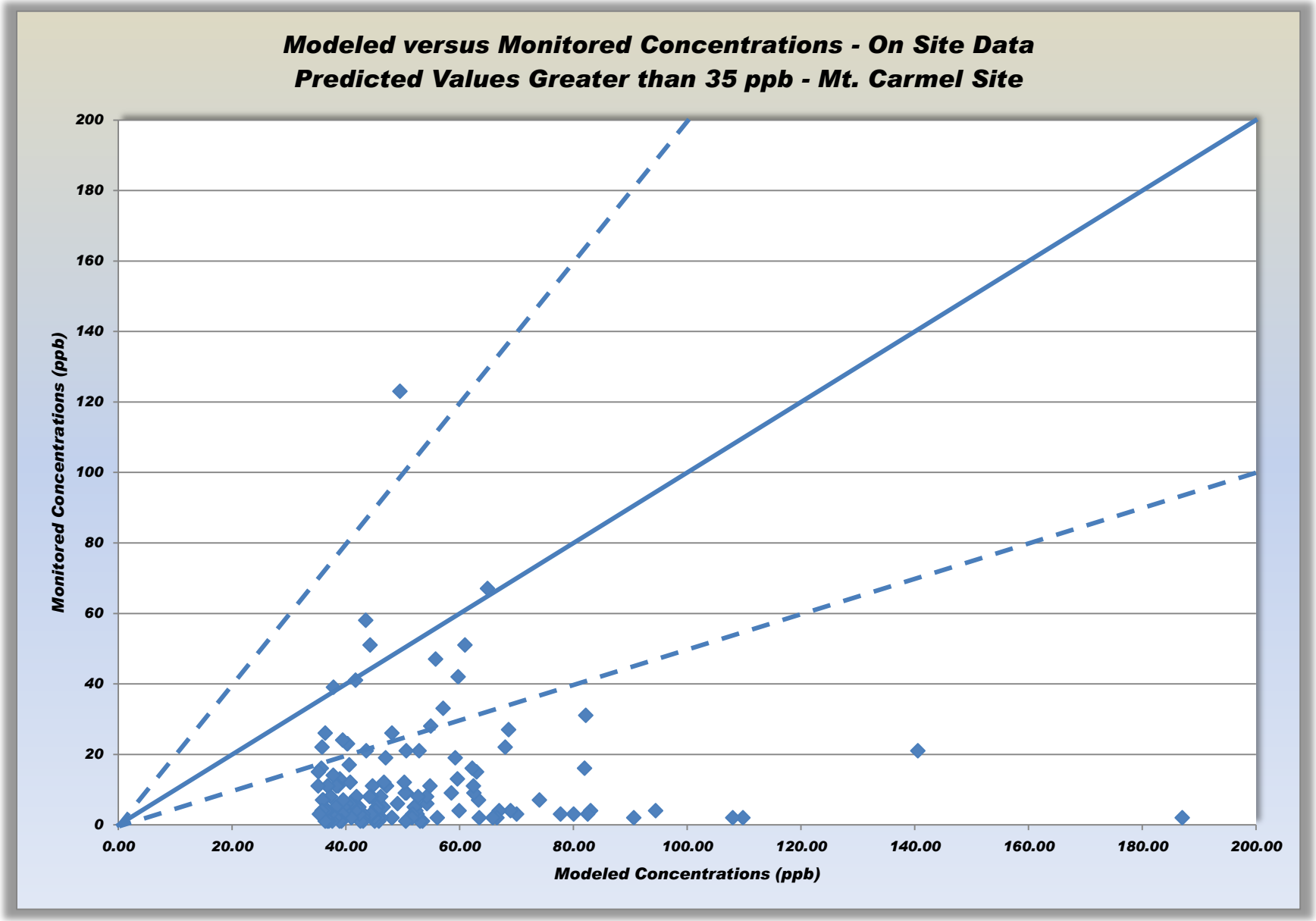

Modeled versus Monitored Concentrations - On Site Data
Predicted Values Greater than 35 ppb - Mt. Carmel Site
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00

Figure 43

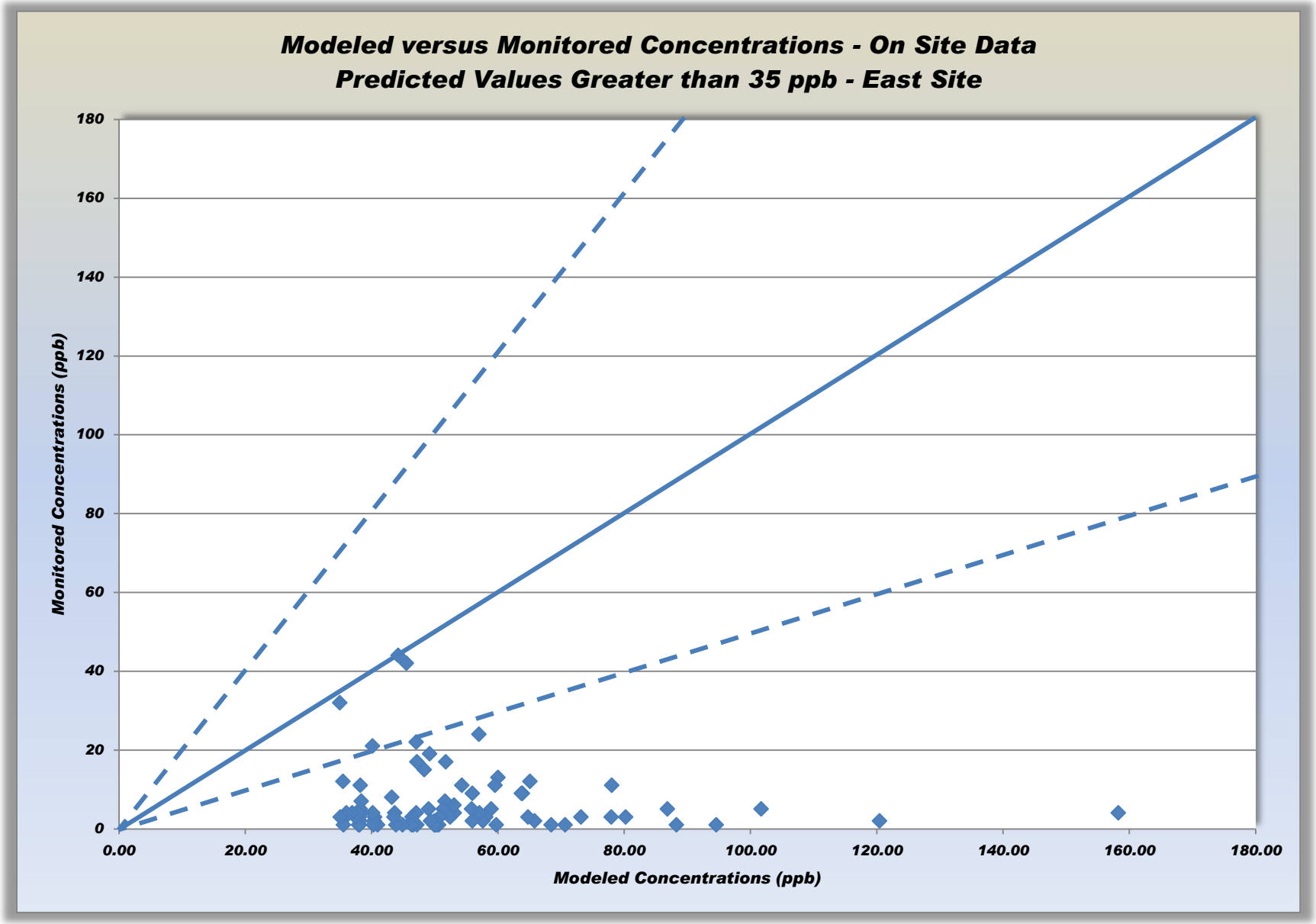

Modeled versus Monitored Concentrations - On Site Data
Predicted Values Greater than 35 ppb - East Site
Monitored Concentrations (ppb)
180
160
140
120
100
80
60
40
20
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Modeled Concentrations (ppb)

Figure 44

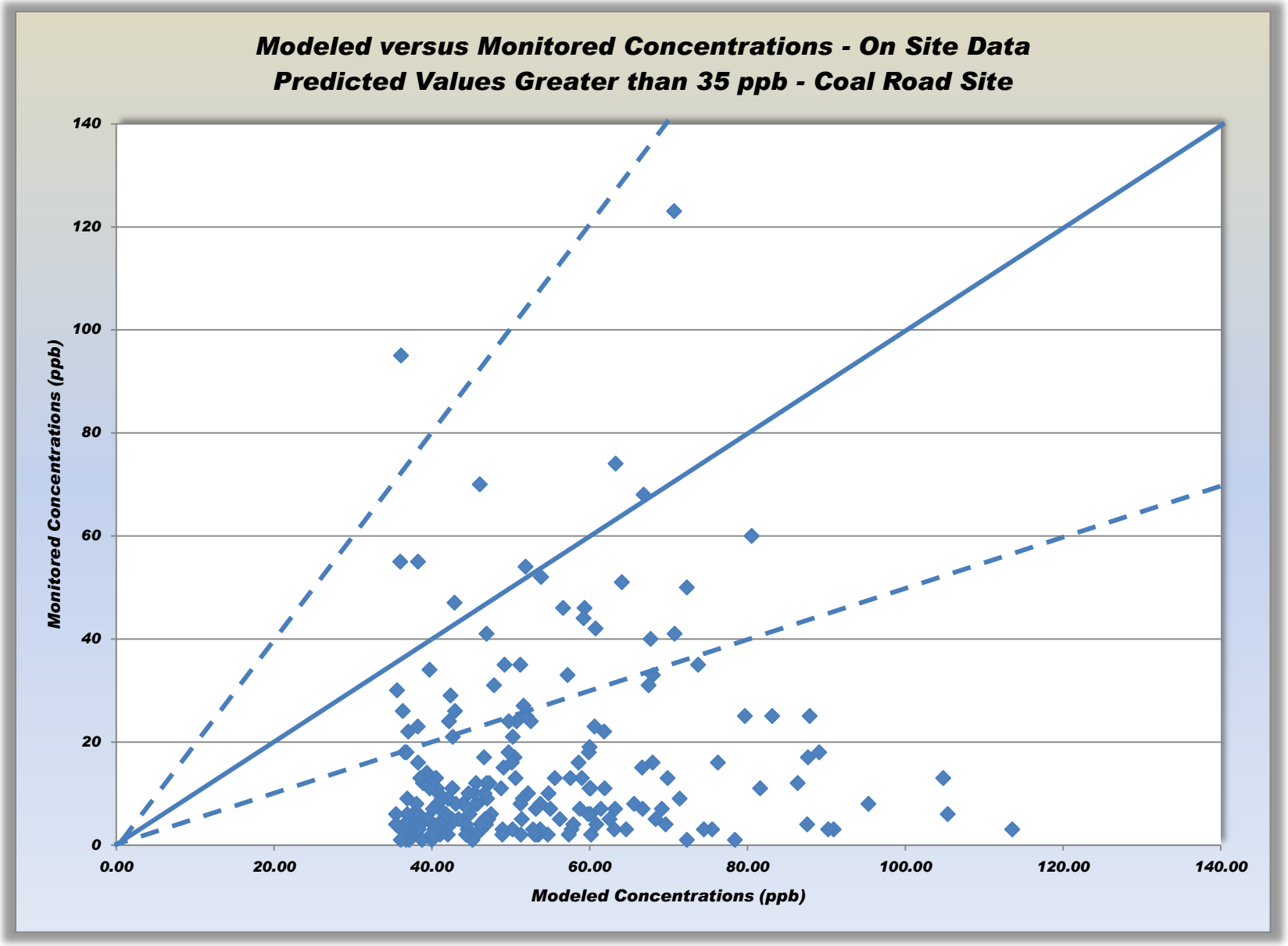
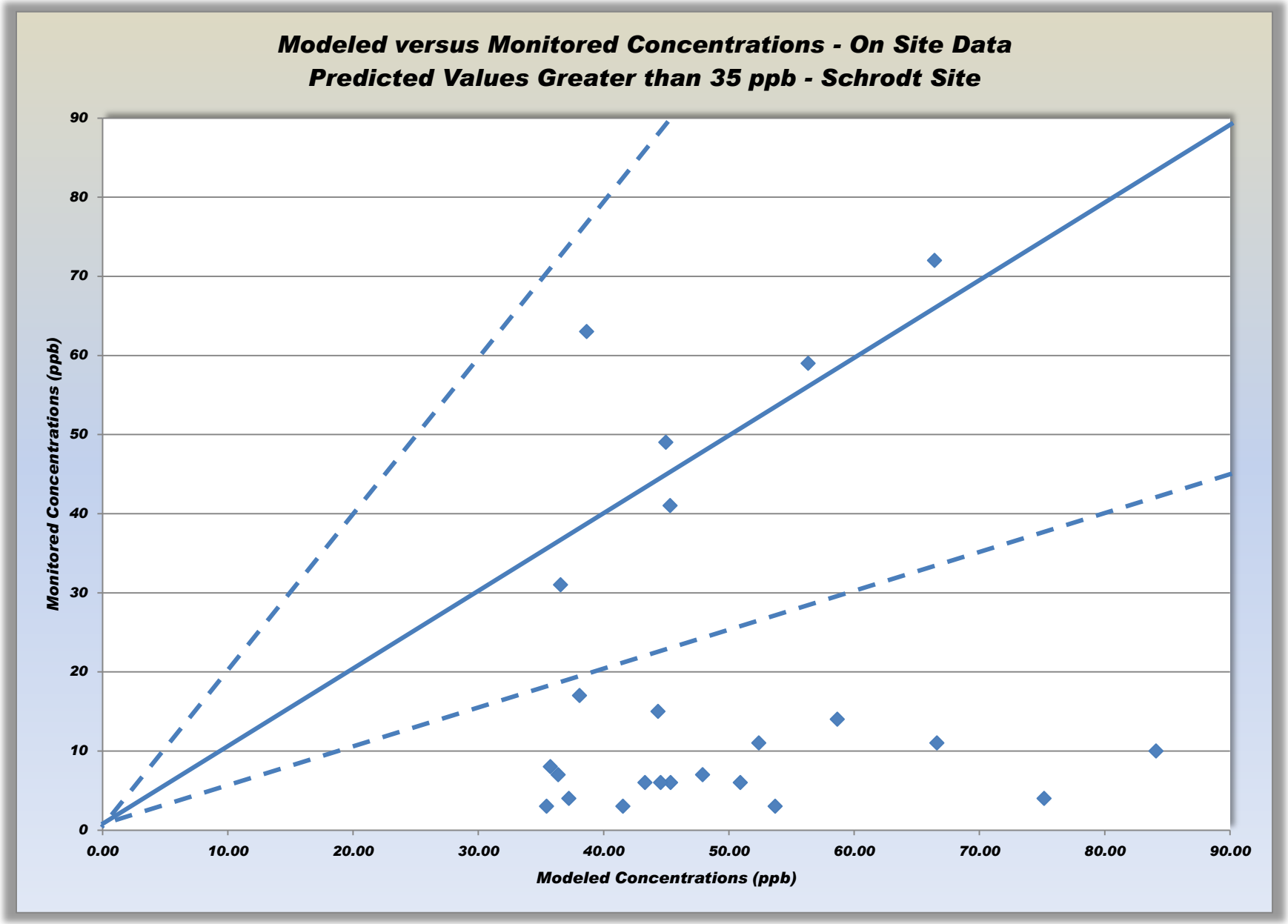

Modeled versus Monitored Concentrations - On Site Data
Predicted Values Greater than 35 ppb - Coal Road Site
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
20
40
60
80
100
120
140
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00

Figure 45


Modeled versus Monitored Concentrations - On Site Data
Predicted Values Greater than 35 ppb - Schrodt Site
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

Adjustment to Emission Rates

In comparing hours without comparing them in time, there is a problem that the predicted concentrations are based on different emission rates than those seen on the monitored days. In an attempt to correct for this, the emission rate on the highest monitored hour was determined as well as the emission rate on the highest predicted hour. The predicted concentration was then adjusted by a ratio of the monitored emission rate divided by the predicted emission rate. This set of corrections was made for all hours with predicted concentrations greater than 35 ppb. The results for each site are discussed below.

Mt. Carmel Site

Figure 46 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Mt. Carmel Site. Of the 135 hours included, 93 are within a factor of two of the monitored values, while 41 are over-predicted by more than a factor of two. One of the values is under-predicted.

East Site

Figure 47 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the East Site. Of the 85 hours included, 68 are within a factor of two of the monitored values, while 17 are over-predicted by more than a factor of two. None of the values are under-predicted.

Coal Road Site

Figure 48 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Coal Road site. Of the 205 hours included, 146 are within a factor of two of the monitored values, while 57 are over-predicted by more than a factor of two. Two of the values are under-predicted.

Schrodt Site

Figure 49 shows a comparison of adjusted predicted concentrations versus monitored concentrations for the Schrodt site. Of the 24 hours included, 23 are within a factor of two of the monitored values, while none are over-predicted by more than a factor of two. One is under-predicted.

SUMMARY

The emission rate correction improves the agreement between predicted and monitored values, the majority of the predictions are within a factor of two (73.5 percent). Another 25.6 percent are over-predicted. Only 0.9 percent is under-predicted by more than a factor of two.

Figure 46

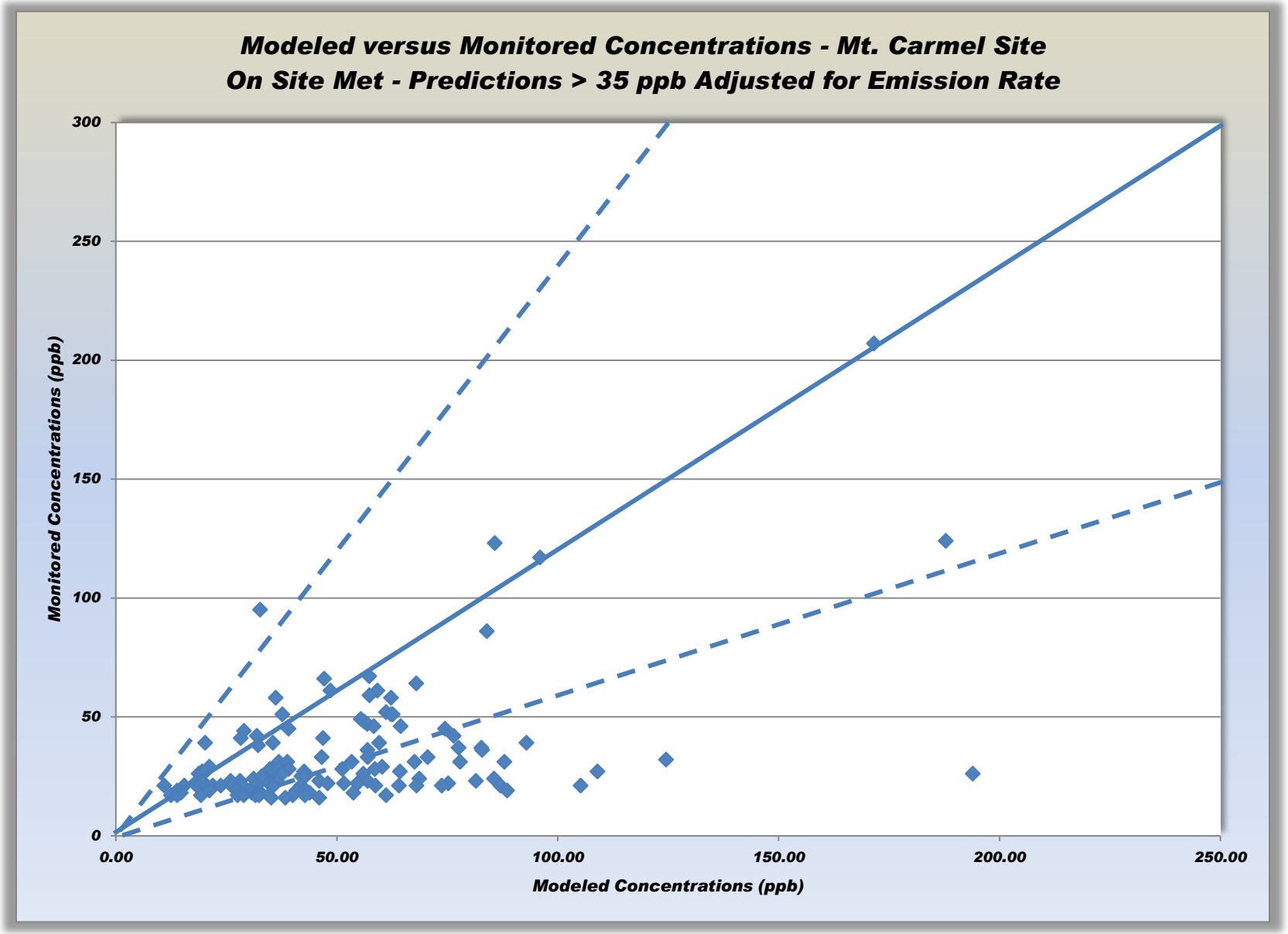

Modeled versus Monitored Concentrations - Mt. Carmel Site
On Site Met - Predictions > 35 ppb Adjusted for Emission Rate
Monitored Concentrations (ppb)
300
250
200
150
100
50
0
0.00
50.00
100.00
150.00
200.00
250.00
Modeled Concentrations (ppb)

Figure 47

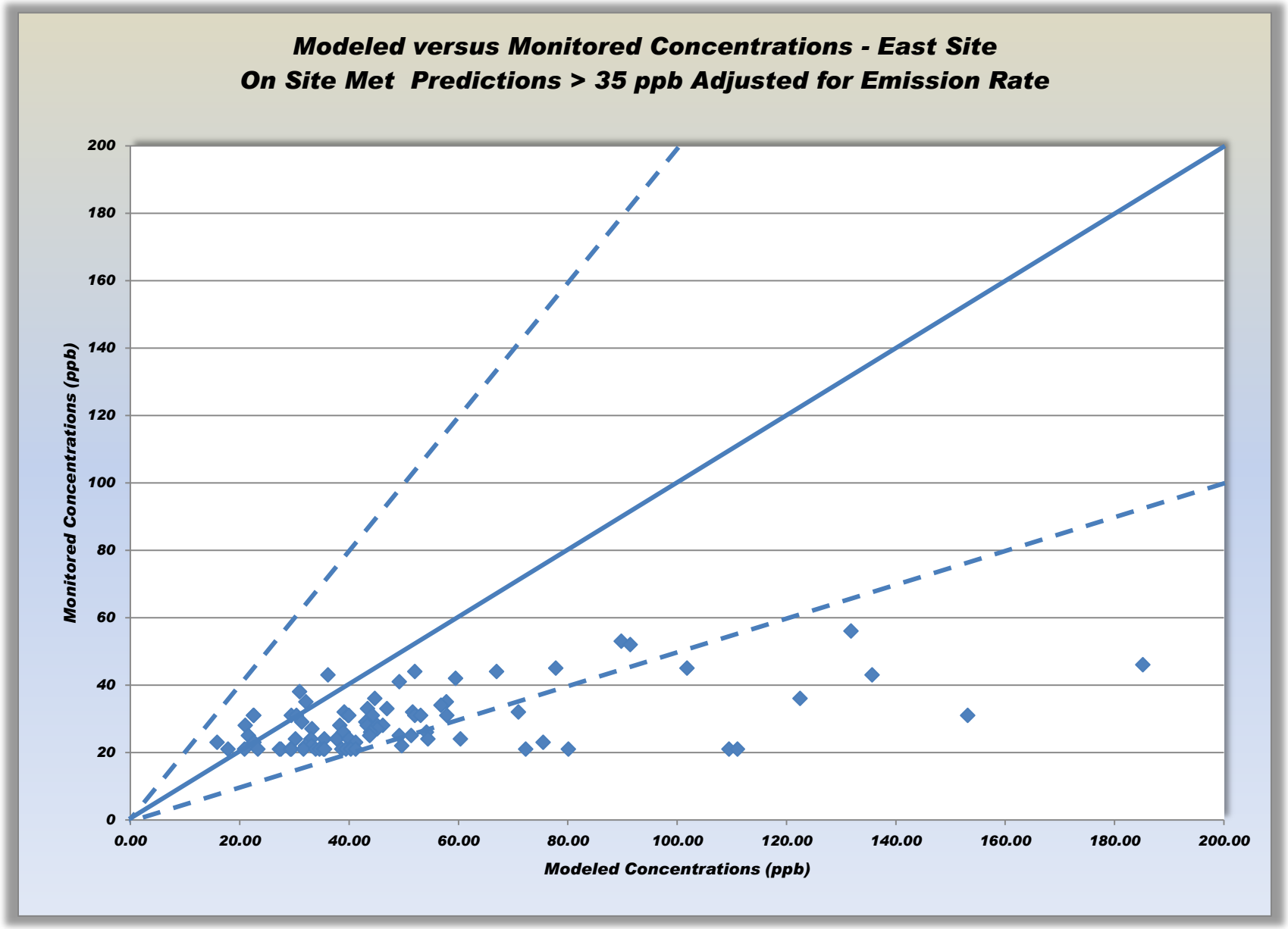

Modeled versus Monitored Concentrations - East Site
On Site Met Predictions > 35 ppb Adjusted for Emission Rate
Monitored Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Modeled Concentrations (ppb)

Figure 48

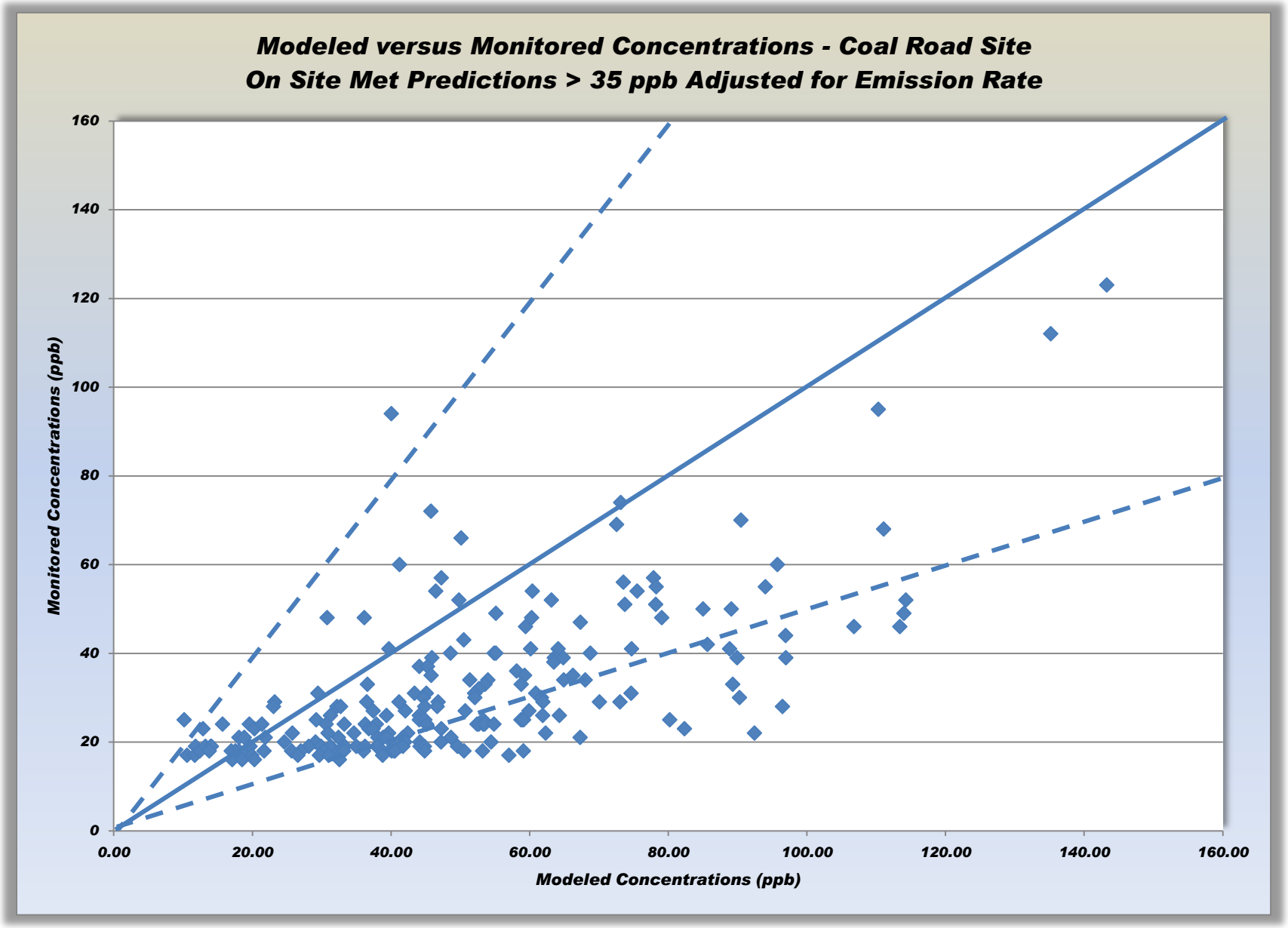
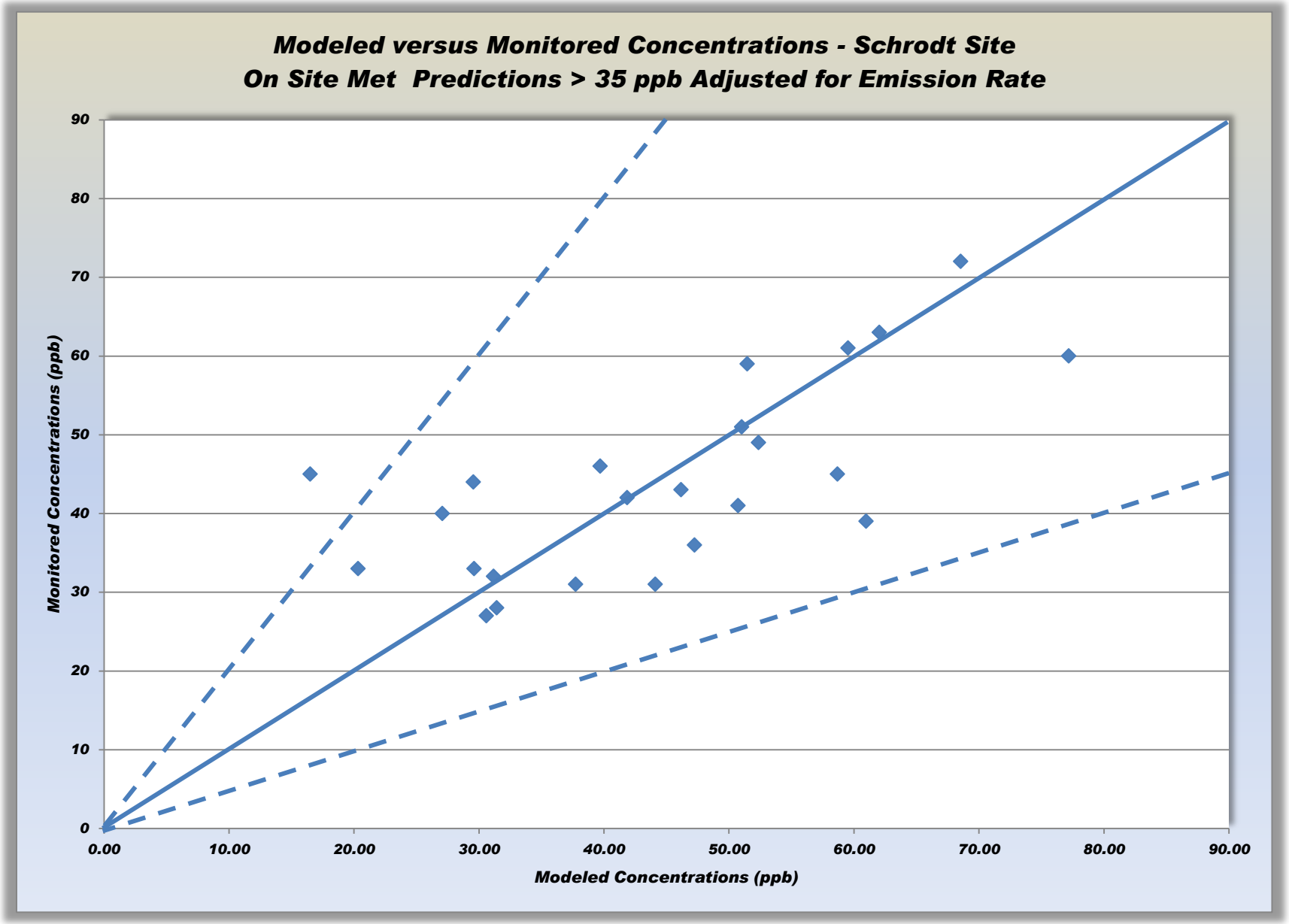

Modeled versus Monitored Concentrations - Coal Road Site
On Site Met Predictions > 35 ppb Adjusted for Emission Rate
Monitored Concentrations (ppb)
0
20
40
60
80
100
120
140
160
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Modeled Concentrations (ppb)

Figure 49


Modeled versus Monitored Concentrations - Schrodt Site
On Site Met Predictions > 35 ppb Adjusted for Emission Rate
Monitored Concentrations (ppb)
Modeled Concentrations (ppb)
0
10
20
30
40
50
60
70
80
90
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

OVERALL SUMMARY

Two attributes of a good refined model are:

1) **That predictions match observations as closely as possible (U.S. EPA has defined an acceptable limit as a factor of two) and**
2) **The model should not be biased; the number of under-predictions should be approximately the same as the number of over-predictions.**

This analysis has looked at observations and predictions in several different ways to determine whether AERMOD meets these two criteria. The following sums up our analysis.

Based on Evansville Meteorology

When looking at predicted values of 35 ppb or greater and comparing the predictions and observations in time, AERMOD grossly over-predicts. Only 16 percent of the predictions are within a factor of two, Over 84 percent are over-predicted by more than a factor of two. The U.S. EPA argues that is inappropriate to compare predictions at exact locations because the wind speed/direction seen at the Gibson power plant may be different that those conditions measured at the Evansville airport. However, their solution is to expand the area of prediction to account for a variation in both wind speed and direction. They then suggest using the highest predicted value within this "box" to compare to the monitored value. This approach would only lead to higher predictions and therefore worsen model performance. We have not followed this approach in this analysis.

When looking at predictions of 35 ppb or greater and not comparing data in time, but adjusting for emission rates, AERMOD shows that 83 percent of the predicted values are within a factor of two, while another 16 percent are over-predicted by a factor of 2 or more. Less than one percent is under-predicted. Using the U.S. EPA's methodology, AERMOD meets the factor of two criteria, but does show a bias toward over-prediction.

IDEM disagrees that this approach, not comparing in time, is appropriate. Since each hour has a different emission rate, comparing different hours without accounting for the difference in emission rates is inappropriate. In an attempt to correct for this difference, we have multiplied the predicted value by a ratio of the emission rate for the monitored hour divided by the emission rate for the predicted hour. While this is not an exact correction, it is the best that can be done with this information.

Based Upon On Site Meteorology

When looking at predicted values of 35 ppb or greater and comparing the predictions and observations in time, AERMOD shows gross over-prediction. Only 13 percent of the observations are within a factor of two, while 87 percent are over-predicted by a factor of 2 or more. Less than 1 percent is under-predicted.

When looking at predicted values of 35 ppb or greater and not comparing the data in time, but adjusting for emission rate, AERMOD shows that 74 of the predictions are within a factor of two. Twenty six percent are over-predicted by a factor of 2 or more. The final 0.9 percent is under-predicted by a factor of 2 or more.

RECOMMENDATIONS

Some of the work carried out shows that AERMOD "blows up" when the wind speed is less than one meter per second. In these cases the model predicts high values at all receptors regardless of wind direction. This is an area that the U.S. EPA should investigate and correct.

Another suggestion also involves wind speed. The U.S. EPA assumes instantaneous transport in AERMOD. In other words if emissions leave the stack they are instantly at the monitor regardless of the wind speed and the distance between the stack and monitor. In reality it takes time for the emissions to reach the monitor. The U.S. EPA should give some consideration to reducing the predicted concentrations by a factor based on the time it takes to get to the monitor. For example, if it takes 30 minutes to get from the stack to the monitor, given the wind speed and distance, the predicted hourly concentration should be cut in half. If it takes more than an hour to get from the stack to the monitor, the predicted concentration should be set to zero.

In the absence of making such a revision to AERMOD, the U.S. EPA should consider using some type of PUFF model which would account for this effect directly.

Based upon these results, AERMOD needs some serious testing to determine the reasons for over-prediction. IDEM is willing to work with the U.S. EPA to begin this process. However, we have no more test cases to recommend similar to the Gibson facility.